HEART DISEASE PATIENTS' AVERTING BEHAVIOR, COSTS OF ILLNESS, AND WILLINGNESS TO PAY TO AVOID ANGINA EPISODES

FINAL REPORT TO

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by

Lauraine G. Chestnut[1]
Steven D. Colome[2]
L. Robin Keller[2]
William E. Lambert[2]
Bart Ostro[3]
Robert D. Rowe[1]
Sandra L. Wojciechowski[2]

1. RCG/Hagler, Bailly, Inc.,
(formerly Energy and Resource Consultants), Boulder, CO
2. University of California, Irvine, CA
3. U.S. Environmental Protection Agency

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EXECUTIVE SUMMARY

Background and History: Cardiac Health Symptoms and Carbon Monoxide Exposure

The University of California, Irvine has been examining the relationship between community exposure to carbon monoxide and the occurrence of cardiac health symptoms, including angina pectoris, in male research subjects with demonstrable ischemic heart disease (atherosclerotic disease of the coronary arteries which impairs blood flow to the heart muscle). During January to May 1985, ischemic heart disease subjects carried electronic monitors to measure personal exposure to carbon monoxide during their normal course of daily activity. Carbon monoxide exposure profiles and biological monitoring demonstrated that heart disease subjects frequently encountered carbon monoxide in the urban environment and at times developed blood levels of carboxyhemoglobin which have been observed in clinical studies to aggravate angina symptoms.

In July 1985 it was recognized that the study's large data base and intact subject pool offered the opportunity for research on defensive behaviors and expenditures made by heart disease subjects in an effort to avoid angina. This led to a cooperative agreement between the U.S. Environmental Protection Agency Office of Policy Analysis, University of California, Irvine, and RCG/Hagler Bailly, Inc. (formerly Energy and Resource Consultants) to demonstrate the feasibility of placing a value on the cost of angina and related cardiac symptoms. Using the established pool of heart disease subjects, willingness to pay to avoid angina episodes was to be elicited, using contingent valuation methods. Information on the cost of

illness related to ischemic heart disease and associated symptoms was collected and compared to what subjects were willing to pay to avoid those episodes. In addition, information was obtained regarding defensive expenditures and behaviors undertaken to avoid or reduce angina symptoms. This report presents the results of this cooperative pilot study. Due to the small, nonrandom sample and exploratory nature of the study design, the results should be interpreted as suggestive only and are intended to guide the design of future research efforts.

Theoretical Framework for Evaluating the Impacts of Carbon Monoxide Exposure on Ischemic Heart Disease Patients

We have developed a framework for assembling many of the components required for the evaluation of the impacts of carbon monoxide exposure on ischemic heart disease patients who experience angina pain.

Chapter 2 contains a review of previous work on the adverse health effects of carbon monoxide on ischemic heart disease patients and the methods used in the University of California, Irvine community exposure study.

A theoretical structure which can be used to evaluate different carbon monoxide standards is also presented in Chapter 2. The basis of this approach is an economic model of individual behavior, in which a person's utility is assumed to be a function of health and the goods or services he consumes. The level of a person's health is modeled as a function of defensive expenditures, pollution exposure, and the biological, social and economic characteristics of the person. It is assumed that a person maximizes utility, which is constrained by available income. Income may be deflated by previous medical expenses and by wages lost through loss of work. This economic model of

individual behavior, when aggregated over a number of individuals, can be used to determine levels of utility for the population resulting from certain carbon monoxide emission standards.

Study Design

Chapter 3 describes the survey methods used to elicit economic information from the 50 subjects in the study. Information on demographics and the adverse effects of angina were obtained by telephone interviews. The adverse effects included time spent sick, lost days of work, partial or full . loss of employment, medical expenditures made in response to illness, rankings of the relative bothersomeness of the effects of angina/heart disease, willingness to pay to avoid additional angina, and defensive expenditures and activities.

Results

Chapter 4 contains the survey results and the analysis of the personal carbon monoxide exposure data. Using multiple measures, the results converge on a picture of ischemic heart disease and associated angina as a burdensome state of health, with substantial medical costs, loss of opportunities to ea~ wages, psychological burdens, and expenditures to avoid further adverse health effects. The results for each type of impact are summarized below,

Cost of Illness

Annual out-of-pocket medical expenditures due to ischemic heart disease for the study subjects averaged $256 per person. This included out-of-pocket cost of treatment and medication, and travel to the physician's office. 0 the r annual medical expenditures incurred by any source (including the Veterans Administration hospital, private insurers, but not the individual) averaged

$4,523 per person. Annual loss of wages due to sick days or partial or full loss of employment due to the illness and associated symptoms averaged $9,581 per person. The total annual cost of expenses and lost earnings thus averaged $14,359 per person. Costs for the "latest angina incident" were reported to be zero or a few cents. Regression analysis suggested no relationship between total reported costs and the rate of angina incidents, reflecting the probable unsuitability of using a COI measure to value changes in angina frequency and intensity.

Lifestyle and Emotional and Physical Effects

In general, the subjects said that the most bothersome effects if a worsening of their condition caused an increase in angina would be decreased ability to do desired activities (recreation, chores, or work), and pain or discomfort. Patients' concern about the worry or inconvenience caused for family and friends, and the possibility of a heart attack or need for bypass surgery were also stressful. Less important, but none the less stressful, were decreased ability to work at a job (for reasons other than income), more non-medical expenses (such as paying for services), more medical treatment expenses, and lost ability to earn income.

Willingness to Pay

The mean willingness to pay to avoid additional angina was $40 per episode among the 42 subjects who responded with a dollar amount. When respondents who gave the answer "I'd pay anything I have to avoid added angina" were coded to be equal to the highest dollar amount they had agreed to

when asked a close-ended question of the form "Would you pay $y per month to avoid 4 (or 8) additional angina episodes per month?", the lower bound on the willingness to pay for all 49 responding subjects was $42 per month. (The frequency of angina episodes in the sample averaged 1 per week or 4-5 episodes per month.) When those who would pay "anything" had their answers recoded to a feasible maximum amount equal to their total monthly income, the average willingness to pay was $103 per episode.

Expenses Due to Defensive Expenditures

Subjects were asked to itemize expenditures for goods or services purchased to avoid additional angina. Twenty-one of the 50 subjects hired services (e.g. , yard work, plumbing, car maintenance) or purchased goods (e.g., lawn mowers, household appliances, and new automobiles) yielding an average annual expense of $2,151 for these 21 subjects. Sixteen of the 21 subjects estimated the number of added angina episodes they avoided by hiring the service they purchase most often or the largest purchase of a good. The average expenditure for these services or goods was $603 for these sixteen subjects. The mean expenditure per episode for these 16 subjects was $38 and ranged from $3.50 to $140. This mean may be compared to the average willingness to pay of $28 per angina episode given by the same 16 subjects. Note that willingness to pay measures the amount a person would pay to avoid additional episodes, given that expenditures for services or equipment have already been incurred.

Activity Patterns and CO Exposure

Data on activity patterns and carbon monoxide exposure in urban locations were collected in an earlier University of California, Irvine research effort. An analysis of these data suggests that ischemic heart disease patients frequently encounter carbon monoxide in the course of their daily activities , and may develop carboxyhemoglobin levels greater than 2.5 percent, a point where aggravation of angina has been observed in clinical studies.

Conclusions

The results of this pilot study suggest that useful information for valuing changes in angina frequency can be obtained from patients with ischemic heart disease. An especially promising result was the consistency between the estimate of defensive expenditures and stated willingness to pay per angina episode avoided. As expected, evaluating changes in angina symptoms is confounded by the complexity and significance of the overall effect on the patient's life of having ischemic heart disease.

This was highlighted by the difficulty found in putting any meaningful cost of illness value on small changes in angina frequency. Specific recommendations for future research efforts are given in Chapter 4.

ABSTRACT

Angina pectoris is a specific type of chest pain associated with atherosclerotic disease of the coronary arteries. This pain is a sensation of tightness or pressure in the chest, and is induced by factors which increase the oxygen requirements of the heart tissue. These factors include physical exertion, emotional stress, and cold weather. Insufficient blood flow to the heart muscle will cause low-oxygen stress, or ischemia, which may be manifest as anginal pain. Oxygen delivery may be further impaired by exposure to the air pollutant carbon monoxide (CO), which binds strongly to hemoglobin and decreases the oxygen-carrying capacity of the blood, thereby causing episodes of angina. Regardless of the cause, recurrent anginal symptoms can reduce the quality of life, restrict activities, and cause psychological stress. But the limited quantitative information on the economic consequences of these effects has constrained the evaluation of public policies to reduce urban CO exposures. This paper presents an economic model of behavior which describes an individual's health and response to environmental pollution. In addition, a survey instrument was developed to measure the economic impacts associated with angina, and was pilot tested with a sample of 50 men with ischemic heart disease. The cost of illness was computed from information elicited on insurance premiums, medication and treatment costs and lost work time; information on expenditures for services or purchases of goods to avoid angina was also elicited. Additionally, the dollar amount that a subject was willing to pay to prevent additional angina was elicited using contingent valuation methods. The performance of the suney instrument suggests that it is feasible to elicit many of the components required in the theoretical model describing the economic behavior of people with angina pectoris who are exposed to CO.

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LIST OF ABBREVIATIONS

CABG	Coronary artery bypass graft
CO	Carbon monoxide
COHb	Carboxyhemoglobin (compound formed by the combination of carbon monoxide with hemoglobin)
COI	Cost of illness
CV	Contingent valuation
ECG	Electrocardiogram
EPA	U.S. Environmental Protection Agency
ERC	Energy and Resource Consultants, Inc.
Hb	Hemoglobin (iron-containing protein respiratory pigments occurring in the red blood cells of vertebrates and transporting oxygen to the tissues and carbon dioxide from the tissues)
IHD	Ischemic heart disease
MET	Metabolic activity unit
MI	Myocardial infarction (heart attack)
O_2Hb	Oxyhemoglobin
PTCA	Percutaneous transluminal coronary angioplasty, also called angioplasty
PEM	Personal exposure monitor
ppm	Parts per million
UC Irvine	University of California, Irvine
VA	Veterans Administration
WTA	Willingness to accept
WTP	Willingness to pay

CHAPTER 1. INTRODUCTION AND SUMMARY

1.1 Background and History

Since January 1985, research, has been conducted at the University of California, Irvine (UC Irvine), examining the relationship between community exposure to carbon monoxide (CO) and the occurrence of cardiac health symptoms, including angina pectoris, A sample of male subjects with demonstrable ischemic heart disease, atherosclerotic disease of the coronary arteries that impairs blood flow to the heart muscle, was assembled from the patient populations of two regional medical centers in the Los Angeles and Orange County areas. During January to May 1985, ischemic heart disease (IHD) subjects carried electronic monitors to measure personal exposure to CO during their normal course of daily activity. CO exposure profiles and biological monitoring demonstrated that IHD subjects frequently encountered CO in the urban environment, and at times developed blood levels of carboxyhemoglobin (COHb) which have been observed in clinical studies to aggravate angina symptoms.

In July 1985 it was recognized that the study's large data base and intact subject pool offered the opportunity for research on defensive behaviors and expenditures made by IHD subjects in an effort to avoid angina. This led to a cooperative agreement between the U.S. Environmental Protection Agency Office of Policy Analysis, UC Irvine, and Energy and Resource Consultants (ERC) to demonstrate the feasibility of placing a value on the cost of angina and related cardiac symptoms. Using the established pool of IHD subjects, alternative measures of the value of avoiding angina

episodes were elicited, using survey research methods. Information was obtained on medical expenses, work loss, defensive expenditures, and willingness to pay to avoid angina episodes. In addition, defensive expenditures and behaviors were related to CO exposure as actually measured in an earlier community monitoring study. This report presents the results of this cooperative study.

1.2 Summary

We have developed a framework for assembling many of the components required for the evaluation of the welfare impacts of carbon monoxide exposure on ischemic heart disease patients who experience angina pain.

Chapter 2 contains a review of previous work on the adverse health effects of CO on ischemic heart disease patients and the methods used in the UC Irvine community exposure Study.

A theoretical structure that can be used to evaluate different carbon monoxide standards is also presented in Chapter 2. The basis of this approach is an economic model of individual behavior, in which a person's utility is assumed to be a function of health and the goods or services he consumes. The level of a person's health is modeled as a function of defensive expenditures, pollution exposure, and the biological, social and economic characteristics of the person. It is assumed that a person maximizes utility, which is constrained by available income. Income may be deflated by previous medical expenses and by wages lost through loss of work. This economic model of individual behavior, when aggregated over a number of individuals, can be used to determine levels of utility for the population resulting from alternative carbon monoxide emission standards.

Chapter 3 describes the survey methods used to elicit economic information from the 50 subjects in the study. Information on demographics and the adverse effects of angina were obtained by telephone interviews. The adverse effects included time spent sick, lost days of work, or partial or full loss of employment, medical expenditures made in response to illness, rankings of the relative bothersomeness of the effects of angina/heart disease, willingness to pay to avoid additional angina, and defensive expenditures and activities.

Chapter 4 contains the survey results and the analysis of the personal CO exposure data. Using multiple measures, the results converge on a picture of IHD as a burdensome state of health, with substantial medical costs, loss of opportunities to earn wages, psychological burdens, and expenditures to avoid further adverse health effects. Angina is a bothersome symptom of IHD for these patients, but it was, in some cases, difficult for subjects to isolate angina symptoms from their disease as a whole. The results for each type of economic welfare measure are described separately. The results must be used with caution because the sample used for this pilot test was small and not necessarily representative of all IHD patients.

Cost of Illness

Annual out-of-pocket medical expenditures due “to IHD for the study subjects averaged $256 per subject. This included out-of-pocket cost of treatment and medication, and travel to the physician’s office. Total annual medical expenditures incurred by society (including the Veterans Administration (VA) hospital and private insurers, but not the individual) averaged $4,523 per subject. Annual loss of wages due to sick days or partial

or full loss of employment due" to angina averaged $9,581 per subject. The total annual cost of expenses and lost earnings to the subject and to society, thus averaged $14,359 per subject across all 50 subjects. Because CO is believed to aggravate angina symptoms in patients who already have IHD, analysis was undertaken to estimate the marginal cost of small changes in angina frequency and the cost of the "latest incident." The results suggest that although the total costs associated with IHD are substantial, the marginal cost of small changes in angina is minimal.

Lifestyle and Emotional and Physical Effects

In general, the subjects reported that the most bothersome effects of an increase in angina would be decreased ability to do desired activities (recreation, chores, or work), and pain or discomfort. Subjects' concern about the worry or inconvenience caused to family and friends, and the possibility of a heart attack or need for bypass surgery were also important. Less important, but still bothersome, were decreased ability to work at a job (for reasons other than income), more non-medical expenses (such as paying for services), more medical treatment expenses and loss of ability to earn income.

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Activity Patterns and CO Exposure

Data on activity patterns and CO exposure in urban locations were collected in an earlier UC Irvine research effort. An analysis of these data suggests that ischemic heart disease patients frequently encounter CO in the course of their daily activities, and may develop carboxyhemoglobin levels greater than 2.5 percent, a point where aggravation of angina has been observed in clinical studies.

CHAPTER 2. MEASURING AND VALUING HEALTH EFFECTS OF CARBON MONOXIDE

The first two sections of this chapter give a brief review of the health and economics literature relevant to measuring and valuing health effects of CO for IHD patients. The third section presents the theoretical framework for the instrument design and data analysis conducted in this study.

2.1 Biological and Health Effects of CO

People with IHD are considered to be particularly sensitive to the toxic action of CO because of their impaired coronary blood flow (Ayres, et al., 1970). Narrowing of the coronary arteries by atherosclerotic plaque limits blood flow, and hence oxygen delivery to the heart muscle (myocardium). When increases in the demand for both coronary blood flow and oxygen delivery exceed the available supply, myocardial ischemia ensues. Ischemia, or low oxygen stress, is manifest in several physiologic endpoints, including decreased force of contraction and changes in electrophysiology of the myocardium, and chest pain.

Chest pain, and the complex of symptoms associated with ischemic cardiac pain, are medically termed angina pectoris, or more simply angina. Chest discomfort or tightness may be accompanied by pain in the throat or lower jaw, or pain radiating across the chest to the arms. The frequency and severity of angina episodes are related to the extent of coronary disease and the work load placed upon the heart muscle. The most common form of cardiac pain is that provoked by exertion.

Myocardial ischemia is quantitatively related to changes in heart rate and blood pressure, and angina sufferers often learn to identify the level of

physical activity that will precipitate the pain. Angina may be brought on by walking uphill or upstairs, hurried walking on level ground, or lifting heavy objects. Pain may also be precipitated by emotional stress; excitement, anger, or tension may increase autonomic nervous system activity and increase heart rate and blood pressure. Exposure to cold temperature may cause constriction of peripheral blood vessels, thereby increasing blood pressure, and in turn raising the cardiac work load. Angina pain comes on quickly, and it is steady and constant, usually lasting for several minutes. Longer periods of ischemic pain are associated with more serious outcomes of myocardial infarction (heart attack). Under most circumstances, angina is relieved by rest, however nitrate medications may, also be taken to increase coronary blood flow and dilate peripheral blood vessels, thereby decreasing the resistance against which the heart muscle pumps.

Exposure to carbon monoxide can decrease the exercise tolerance of IHD subjects who suffer angina. Inhaled CO displaces the oxygen in blood hemoglobin and alters the binding characteristics of oxyhemoglobin, further decreasing oxygen supply to the myocardium (Roughton and Darling, 1944). In standardized exercise tests, Andersen et al. (1973) observed statistically significant decreases in exercise duration to the onset of angina after four hours exposure to 50 or 100 ppm CO. The carboxyhemoglobin (COHb) concentrations resulting from these relatively low-level exposures were 2.9 and 4.5 percent, respectively. These COHb concentrations may be attained by nonsmoking residents of metropolitan areas (Wallace et al., 1987; Akland et al., 1985; Radford and Drizd, 1982), and therefore represent an important public health concern. Currently, the Health Effects Institute and the California Air Resources Board are funding research to replicate and extend the Andersen et al. (1973) study. Other clinical studies by Aronow (1981) and

Aronow and Isbell (1973) have suggested aggravation of angina at COHb levels near 3 percent. However, the methodology employed in these studies has not withstood rigorous scientific review (U.S. EPA, 1984 a and b).

Although provocation of angina is the endpoint of interest in our study, decrements in cardiac function have been measured in other clinical studies, which support the hypothesis of increased health risk from CO exposure. Significant decreases in left ventricular ejection fraction, indicating a decrease in the forcefulness of contraction of the myocardium, were observed in IHD patients whose COHb levels were elevated to 5.9 percent. In healthy, nonsmoking individuals, free of cardiac disease, COHb levels greater than 5 percent exceed the compensatory response of the cardiovascular system to hypoxic challenge; oxygen demands exceed the supply provided by increased . coronary blood flow (Ayres and Grace, 1970), and exercise performance is generally impaired (Ekblom and Hout, 1972; Horvath et al., 1975; Weiser et al., 1978; Klein et al., 1980). The consistent demonstration of decreased aerobic work capacity in healthy individuals at the 5 percent COHb level lends indirect support to the Andersen et al. (1973) observations of angina aggravation in IHD subjects at 3 percent COHb. At the present time, CO exposure has not been unequivocally associated with changes in the electrophysiology of the heart muscle. Human and animal studies are limited in number and provide inconsistent data on disturbances in conduction velocity and heart rhythm (DeBias et al., 1973; Davies and Smith, 1980; Foster, 1981).

Epidemiologic evidence on the relationship between CO exposure and increased incidence of myocardial ischemia also is limited. In Los Angeles, total deaths and deaths from atherosclerotic heart disease (myocardial infarction) were significantly associated with daily mean outdoor CO concentration (Cohen et al., 1969; Hexter and Goldsmith, 1971). Kurt et al.

‘(1978, 1979) considered the specific relationship between community CO levels and the incidence of angina in Denver, Colorado. The incidence of cardiorespiratory complaints, including angina, were significantly associated with 24-hour mean CO levels exceeding 5 ppm. These epidemiologic studies have assumed that outdoor levels of CO are generally representative of personal exposures. The validity of conclusions based on this asumption is questioned by later research demonstrating that time-weighted personal exposures are not strongly correlated with CO measurements at nearby outdoor fixed-site locations (Akland et al., 1985; Hartwell et al., 1984; Johnson, 1984).

Previous Assessments of Community CO Exposure

The most comprehensive population-based study of community CO exposures was performed in the winter of 1982-83 by the U.S. EPA in the cities of Denver, Colorado, and Washington, D.C. (Akland et al., 1985). In each metropolitan area, five-hundred nonsmoking residents, age 18-70, were randomly selected to carry a personal exposure monitor for one or two 24-hour periods. Each subject kept a written diary of activities and locations during their monitoring day, and samples of end-expired breath were collected at the end of the monitoring period for analysis of CO content and estimation of COHb level. Microenvironment associated with automobile activity displayed the highest mean personal exposures to CO (7-14 ppm) and included exposure indoors in public garage, service station, or auto repair facility, and in transit in a motor vehicle (Hartwell et al., 1984; Johnson et al. , 1984). Moderate exposures (2-5 ppm) were measured in indoor public places such as restaurants, stores, and health care facilities. Schools, residences, and outdoor recreational areas generally demonstrated lower mean exposures (0.5-2 ppm).

In Denver, 3 percent of the daily maximum personal exposures exceeded the 35 ppm l-hour average federal standard, and 11 percent exceeded the daily maximum 9 ppm 8-hour average federal standard. In Washington, while no subject's personal exposure exceeded the l-hour standard, 3.5 percent of personal exposures exceeded the 9 ppm standard (Akland et al. , 1985; Ott et al., 1987).

Fixed monitoring sites in Denver and Washington tended to overestimate . mean exposures for the population, predicting that the daily 9 ppm 8-hour standard in Denver and Washington would be exceeded 25 and 7 percent of the time, respectively. When personal exposure monitoring data and breath estimates of blood COHb were entered into the Coburn equation to estimate recent CO exposures, 10 percent of the nonsmoking population of Washington, D.C. was estimated to have exceeded the 9 ppm 8-hour ambient standard (Wallace et al., 1987). The authors based this upward revision primarily on the negative measurement bias observed in the electronic instrumentation used to measure personal CO exposure. The Denver and Washington studies do identify portions of the population at risk to CO exposure by characteristics of working outside the home, commuting time greater than 6 hours per week, high exposure source at work, and unvented gas stove present at the residence (Akland et al., 1985).

As part of the 1976-1980 National Health and Nutrition Examination Survey (NHANES II), over 8,000 blood samples were analyzed for COHb content and classified according to demographic and personal characteristics (Radford and Drizd, 1982). Wintertime mean COHb concentrations in never-smokers living in urban areas, aged 12-74 years, was 1.25 percent. Over 4 percent of nonsmoking adults displayed COHb levels greater than 2.5 percent; however, the exact source of elevated exposure could not be identified. The subgroup comprised of children aged 3-11, if used as a proxy for urban residents free of

confounding exposures from occupational and personal tobacco use, had mean COHb levels of 1.01 percent during winter months when COHb levels were substantially higher. In the winter, 3.3 percent of the children had COHb levels in excess of 2.5 percent. These results, when extrapolated to the nonsmoking adult population, indicate that 3-4 percent of the population may be exposed during the winter to CO levels exceeding the 9 ppm 8-hour and 35 ppm l-hour standards chosen to keep COHb levels from rising above 1.5 percent.

In summary, population-based sampling of CO exposure and COHb levels indicates that a portion of the population living in metropolitan areas is exposed to higher CO levels because of personal activities. The results of the Denver and Washington surveys suggest that these higher exposures are more strongly associated with mobile sources, gas stove use, and passive smoking, than with occupational settings characterized by high exposure. While the " sensitive population of interest, IHD subjects, "may not necessarily be found in high-exposure occupations, their normal urban activities. may place them in situations which include exposure to the emissions of gas stoves, furnaces and space heaters, and gasoline-powered appliances, and also to environmental tobacco smoke. The Program in Social Ecology at UC Irvine conducted a field study during January to May 1985 to characterize the activity patterns and CO exposures of men diagnosed with severe IHD.

Community Exposure to CO Experienced by IHD Subjects

In the UC Irvine study, a sample of individuals was selected from medical records at UC Irvine Medical Center and Long Beach VA Medical Center. As identified from coronary angiogram data, each individual invited to participate in the study had at least 50 percent occlusion of one of the three

major coronary arteries. A further criterion for selection was "objective" electrocardiographic evidence of ischemia during exercise stress testing. Since angina is a "subjective" indicator of ischemia, and may or may not occur reproducibly during exercise tests, the presence of angina during clinical stress testing was not a prerequisite for participation in the research program.

Subjects with IHD were continuously monitored as they went about their normal day-to-day activities. The subjects wore a personal CO monitor recording minute average exposures in an electronic memory and, at times, a Helter ambulatory ECG monitor. Only the results of the exposure monitoring were used and presented in the current study of economic risks, and therefore electrocardiographic measurements will not be presented. Subjects maintained a diary of activities, locations, and symptoms during 24-hour sampling periods. The subjects also provided end-expired breath samples into collection bags during the monitoring days to assess COHb levels which, when analyzed, were compared with levels predicted from CO exposure profiles.

While wearing the CO monitors, subjects were asked to maintain a diary of their daily activities. The time-activity diaries were designed to provide detailed information on the subject's surroundings and promixity to potential pollution sources. Diaries for this study also requested detailed information on the physical state of the individual: activity level, health symptoms, and medication taken. These data were used to estimate myocardial oxygenation demands, identify periods of perceived ischemia as manifested in angina pectoris or palpitation, and corrective actions. Subjects completed questionnaires on potential exposures to CO in the workplace and residence as well as background on health and lifestyle. Subjects were asked to wear CO personal exposure monitors (PEM) for five 24-hour periods: four weekdays and,

if possible, 1 weekend day. While wearing the monitor, subjects were asked to provide end-expired breath samples at six specified intervals. These samples were used to estimate COHb.

This monitoring served several purposes, including characterization of the time-activity schedules of IHD subjects for comparison against data for the normal population, characterization of the CO exposure pattern encountered in normal urban activities, and estimation of the resulting COHb experienced by an IHD subgroup. Forty-three (43) subjects participated in CO monitoring, contributing 159 person-days of personal exposure data. Thirty of these subjects participated in the present study on economic impacts of angina. Twenty additional subjects were specifically enlisted to participate in the economic impact research.

The results of this field study are presented in Section 4.4. The co exposure information from the personal exposure monitors characterized the types of exposure-activity environments encountered by IHD patients. This information is useful in evaluating the risk of IHD patients developing particular levels of COHb in their urban movements. The 1440 individual one-minute CO averages, making up the 24-hour monitoring period, were entered into uptake-elimination model algorithms to predict the individual's COHb response to exposure. Exposure profiles from individuals who had participated in the original 1985 field survey were used as input in the analysis of non-medical defensive behaviors, presented in Section 4.3.

2.2 Background on Economic Health Valuation

There are two different ways commonly used to approach the economic valuation of changes in health. One is cost of illness (COI), which is

historically more common. The COI approach is described by Rice (1966) and Hartunian et al. (1981), and involves estimating the medical expenditures and productivity losses associated with the health condition of interest. It has long been recognized that COI measures do not reflect the full welfare impact of a health problem because the financial impact of an illness is only part of the story. Health problems also typically involve discomfort, inconvenience, and activity restrictions that go beyond what is reflected in direct expenditures and lost income.

The second approach to the economic valuation of changes in health is willingness to pay (WTP). The WTP measure is defined as the change in income that would cause the same change in utility (well-being) for the individual as that caused by the health condition of interest. WTP measures are more appropriate than COI measures for comparison to the costs of public policies to protect human health, such as pollution control regulations, because they are a dollar measure of the full impact of the potential change in health. In general, WTP measures are expected to exceed COI measures for the same change in health, although there may be some exceptions. It is also important to note that there may be a difference in who incurs the impact of cost. For example, an individual who gets paid sick leave may not consider his lost productivity as a cost to himself, but it is a cost to society.

WTP measures, although theoretically more desirable for benefit-cost analysis, are more difficult to obtain than COI estimates. There are basically two types of approach for estimating WTP for changes in health. The first is called the "averting behavior" method, and involves inferring WTP from real-life situations where individuals are choosing a tradeoff between some benefit or cost that has a dollar value and some perceived or derived change in health. The second method, termed "contingent valuation," involves

asking subjects" to respond to a hypothetical situation in which such a tradeoff is required.

For this study, a survey instrument was designed to obtain both COI and WTP information for evaluating changes in angina symptoms. WTP estimation involved both direct WTP questions and actual trade-off situations presented to subjects. The emphasis of the study is on the WTP estimates, but the COI information seines as an important standard for comparison.

2.2.1 Previous Studies Estimating WTP for Changes in Health

To date, few studies have been conducted estimating WTP for changes in non-fatal health effects that may be associated with air pollution exposure. Methods for estimating WTP for changes in morbidity are in developmental stages and our study contributes to this method development effort. Four studies have been conducted that have important similarities to our research effort: Loehman et al. (1979), Rowe and Chestnut (1985, 1986), Tolley et al. (1985), and Dickie et al. (1986, 1987). This discussion is not intended as a detailed review of these studies, but as an explanation of how this study builds upon previous research efforts.

Loehman et al. (1979) conducted a mail survey concerning common respiratory symptoms such as coughing and sneezing, shortness of breath, and head congestion. The sample was drawn from the general population in the Tampa, Florida area. The questionnaire was quite brief, explaining simply that policymakers could use information about how the public values the avoidance of specific health problems. Respondents were asked to select among a list of possible dollar values for avoiding one or seven days of minor or severe symptoms, for each of three types of symptoms. It was observed that

subjects offered higher dollar amounts for preventing the severe symptoms. This would be expected and suggests some logical consistency, The results also indicated that values per symptom day avoided were lower when respondents were asked about seven days than when they were asked about one day. This finding is consistent with economic theory concerning diminishing marginal utility of additional amounts of a good, although health is not a typical economic good, such as apples and automobiles, and might not necessarily show all the same properties.

The research of Loehman et al. (1979) has important implications for policy analysis. Evaluation of policy actions that will result in changes in the amount of illness is more complicated than simply applying a fixed value per unit of illness to the amount of illness expected to be avoided. The value per unit of illness is expected to be a function of the amount of illness reduced or avoided, i.e., values estimated for a one-day-per-year reduction in head congestion per person should not be simply multiplied by 20 to evaluate a program that will prevent 20 days per year of head congestion per person.

Another finding in the Loehman et al. (1979) results is that mean values were significantly larger than median values for each symptom. This indicates a skewed distribution, and the authors of this study suggest that the median values were actually more representative of the central tendency of the responses than the mean values. The mean values were influenced by a few responses that were very large compared to most of the responses. One question that has subsequently been raised is whether some of these large bids may be protest responses by individuals who object to putting dollar values on health. This is being explored further in subsequent research, including the study reported here.

Tolley et al. (1985) conducted personal interviews in a general population sample to assess WTP to prevent seven common symptoms, including cough, head congestion, headache, and nausea. Another set of questions also elicited dollar values for preventing angina symptoms. Each symptom was described, and the respondents were asked to estimate the most they would be willing to pay to prevent having the symptom on a given number of days in a year. Mean values were generally of the same order of magnitude as the mean values obtained by Loehman et al. (1979). The WTP estimates per day of symptoms avoided were significantly lower when the question was for 30 days rather than one day, a result also consistent with the Loehman study. The findings of Tolley et al. (1985) indicated that values for preventing symptoms were higher for respondents who more often experience those symptoms, and for respondents who reported being in poor general health. The results from questions addressing angina symptoms are inconclusive because respondents were asked to consider angina symptoms whether or not they had the kind of heart condition that is associated with angina. This type of approach is problematic for two reasons: 1) people who have never had angina probably have a more difficult time estimating a value for preventing angina symptoms than symptoms they have experienced, and 2) the CO policy issue is not whether people without IHD will develop IHD and experience angina, but whether people with IHD will experience angina more frequently than they would otherwise. It may be appropriate to ask healthy subjects about values for preventing risks of developing chronic illnesses if such a risk is at issue for a particular air pollutant, but actual development is not the primary concern with regard to CO and angina.

Dickie et al. (1986, 1987) have pioneered an application of the averting behavior method for estimating WTP for reduction of symptoms potentially

related to ozone exposure, such as coughing, throat irritation, sinus pain, and headache. The averting behavior method considers behaviors the individual may undertake to reduce symptoms and infers a value for the reduction in symptoms from the cost of the averting behavior. The averting activities considered in this study were automobile air conditioning, home air conditioning, home air purification, and switching from gas to electric cooking.

By analysis of a model of utility-maximizing behavior with respect to health, Dickie et al. (1986, 1987) derived the following expression for marginal WTP for symptom reduction.

$$WTP - Qi/Si \qquad (2\text{-}1)$$

where: Qi - full price (including time) of the ith averting activity

Si - marginal product of the ith averting activity in reducing the symptom.

The common sense interpretation of this expression is that the individual will put resources into the averting activity to the point where the value of the marginal benefit (the utility gained by reducing the symptom) just equals the marginal cost of obtaining the symptom reduction. The averting activity can therefore be interpreted as a market activity in which the individual can be observed “purchasing” a symptom reduction, and the “price” paid can be interpreted as an estimate of the WTP for the symptom reduction.

Dickie et al. (1986, 1987) estimated Equation (2-1) for several different symptoms by first estimating separate symptom production functions that show the relationship between the probability of experiencing the symptom and

whether the averting activity was undertaken. Equation 2-1 was then evaluated for a single day of each of the symptoms avoided. The estimated values tended to be lower than the Loehman et al. (1979) and Tolley et al. (1985) mean WTP responses for similar symptoms on a single day, but were closer to the per-day values obtained when respondents were asked about avoiding 7, 30, or 90 days of each symptom in a year. For comparison, Dickie et al. (1986, 1987) also asked direct WTP questions concerning avoiding one day of each symptom. The mean responses were similar to those obtained by earlier studies,

The application of the averting behavior method is an important innovation for using actual behavior to infer WTP values for changes in symptoms, but significant limitations remain. For example, most of the behaviors involve benefits beyond the reduction of symptoms, and may in fact be primarily motivated by some other purpose, such as obtaining a more comfortable living environment.

An averting behavior approach is also used in the analysis of angina symptoms presented in this report. An expression like Equation 2-1 is evaluated using data obtained from the respondents. This is discussed more fully in subsequent sections of this report (e.g., in Section 4.3).

Rowe and Chestnut (1985, 1986) conducted a study with a panel of asthmatics to obtain information on the benefits of reducing or preventing asthma symptoms. Information was obtained from about 90 asthmatics living in Glendora, California, concerning behavior adjustments they made to avoid or reduce asthma symptoms and the medical costs related to the asthma, and what they would be willing to pay to have their symptoms reduced. Information was obtained on the effect of the asthma symptoms on their lives, and included financial and nonfinancial impacts. The study also involved an analysis of averting behaviors undertaken on days when subjects were concerned that their asthma symptoms might occur.

The study augmented the conventional contingent valuation approach by obtaining information on the subjects' beliefs concerning the primary benefits of reduction in asthma symptoms. On average, the subjects ranked reductions in discomfort and activity restrictions as more important than reductions in medical expenses and income loss (the primary components of a COI measure). This supports the hypothesis that COI measures underestimate the total value of reducing or avoiding asthma symptoms. Additional information obtained about each subject also allowed consistency checks to evaluate the credibility and validity of the responses to the direct WTP questions. Since a few very high responses can unduly influence mean values, and contingent valuation questions are hypothetical and do not require that an actual payment be made, personal characteristic information is essential for valid interpretation of results of contingent valuation questions. Hopefully, future WTP efforts will be better structured to understand and evaluate the validity of the responses given to these contingent valuation questions.

2.3 Theoretical Framework for the Study Design

An economic model of individual behavior and utility maximization with respect to health is based on a theory of consumer behavior developed by Becker (1971). The model was first used by Grossman (1972) and later applied to the health effects of environmental pollution. The basic concept is that the individual combines purchased goods and services with his own time and skills to produce desired outputs that contribute to his utility (or well-being). What this means for health is that the individual uses medical care and health-enhancing activities, such as exercise and sleep, to maintain his health at an optimal level, given his preferences, time and dollar budget

constraints, biological endowment, and effectiveness at producing health. Thus, given certain constraints, the individual chooses his level of health. The relationship between the individual's health and health-enhancing expenditures and activities is referred to as the health production function. Technology, biological endowment, and pollution levels will influence this relationship. The model provides an analytical tool for examining the effect of changes in health on the individual's utility and for identifying factors that will be helpful in evaluating changes in health.

The basic health production function model of consumer behavior presented below is a synthesis of the models presented by Gerking et al. (1983, 1986) and Barrington and Portney (1987), developed specifically to analyze WTP for changes in pollution that may affect health. This model is useful because it can be used to define specific components of an individual's WTP for changes in his own health by analyzing the ways that health can be expected to affect an individual's utility. The results of the analysis suggest ways to approach the estimation of WTP and give criteria by which to evaluate the completeness of WTP estimates.

The individual's utility is a function of the goods and services consumed and his or her state of health, which directly influences the enjoyment of life's activities and how good the individual feels. The direct effects of the individual's state of health on utility would include pain and discomfort experienced during an illness.

$$U - u(X,H) \qquad (2\text{-}2)$$

Where:

U = the individual's utility in a given time period

X = goods, services, and leisure activities the individual consumes that are unrelated to his or her health

H = the individual's state of health

The individual's state of health (H) is a function of defensive expenditures and health-enhancing activities undertaken. These include preventive medical care, exercise, and diet; exogenously determined levels of pollution; and biological, 'social and economic characteristics of the individual (e.g., congenital conditions, age, and education) 'that influence the effectiveness with which he can maintain a given state of health.

Two simplifying assumptions are used in this presentation of the model: pollution levels are exogenous, and defensive expenditures and activities affect utility only through their effect on health. The model could treat pollution exposure as an endogenously determined variable influenced by the actions of the individual, but that is not the focus of this analysis. Relaxing the second assumption would result in a more complex model, but in reality many defensive activities may produce utility in more than one manner; for example, playing tennis produces enjoyment of the game jointly with the health benefit of the exercise. This problem is addressed in the study design and analysis but is not included in this presentation of the model.

The level of defensive expenditures and activities is chosen by the individual as a function of the individual's health, environmental pollution,

and other factors.' The health production function and the defensive expenditures function are therefore simultaneous equations.

$$H = h(D,P,Z1) \quad (2\text{-}3)$$

$$D = d(H,P,Z2) \quad (2\text{-}4)$$

Where:

D = Defensive expenditures and activities

P = Pollution

Z1 = biological, social and economic characteristics of the individual

Z2 = biological, social and economic characteristics of the individual that influence defensive expenditures and activities

Duration of illness and medical expenditures made in response to illness enter into the individual's budget constraint because they affect the amount of time and money the individual has for other things, but they do not directly enter the individual's utility function. These medical expenditures do not prevent additional illness but may mitigate the discomfort and loss of activity that accompany illness.

$$Ts - t(H) \quad (2\text{-}5)$$

$$M - m(Ts) \quad (2\text{-}6)$$

Where:

Ts = time spent sick

M = medical expenditures in response to illness

The individual faces the following time and budget constraints.'

$$X*Px + D*pd + M*Pm \;.\; w*Tw \;\; I+ \qquad (2\text{-}7)$$

$$X*Tx + D*Td + M*Tm + Ts + Tw = T \qquad (2\text{-}a)$$

Where:

Pi - price per unit of i, for i - x, d, andm

Ti - time per unit of i, for i - x,'d, and m

Tw = time spent working

w = the individual's wage rate

I = nonwage income

T = total time available

Equations 2-7 and 2-8 can be combined into a "full income" constraint by assuming all time is valued at the wage rate, and defining a combined dollar and time cost: Qi - Pi + w*Ti. Using w as the value for all time assumes that"

individuals choose to work to the point where the marginal benefits of working (the wage earned) just equal the marginal costs in terms of the value of time lost from other activities. In this simple model, it is also assumed that all costs of defensive and medical care are borne by the individual and that prices in the medical care market reflect marginal social costs of producing medical care.

$$X*Qx + D*Qd + M*Qm + w*Ts = w*T + I \qquad (2\text{-}9)$$

The individual can be expected to choose levels of X and D that maximize utility (Equation 2-2) subject to the constraints of Equations 2-3 to 2-9. The choice is made by allocating time and dollar expenditures such that the marginal benefits equal the marginal costs of each good and sevice for the individual. For defensive expenditures, for example, the marginal benefit is the dollar value of the improvement in utility obtained by an additional unit of defensive effort, plus the medical expenditures that no longer have to be incurred, and the opportunity costs of time not spent in sickness as a result of the unit increase in defensive efforts.[1] The marginal cost is the unit cost of defensive efforts, including both money and time (Qd). This means that the amount of defensive efforts undertaken will depend on the effectiveness of these efforts in maintaining health and on the costs and discomfort associated with time spent sick, as well as on the direct costs of the defensive efforts.

Dickie et al. (1986, 1987) have used this model to derive the following expression for the dollar amount that would keep utility constant if a change

[1] The first order condition for defensive efforts (D) is $\partial L/\partial D - U_H*H_D - a(Qd + M_{TS}*TS*H_D - 0$, where subscripts denote partial derivatives.

occurs in H. This is the marginal WTP to prevent or obtain a potential change in H. An expression for willingness to accept (WTA) compensation would be the same, only the reference level of utility would be different. WTA for a decrease in health is the increase in dollar income that would offset the decrease in utility associated with the decrease in health. For an increase in health, the WTA would be the decrease in dollar income that would offset the increase in utility associated with the increased health.

$$WTP_H = H_D * Qd \qquad (2\text{-}10)$$

Where:

WTP_H - marginal WTP for changes in H

H_D - the partial derivative of H with respect to D

Equation (2-10) is equivalent to Equation (2-1) and suggests that when an inexpensive defensive action is available to offset a potential decrease in H, then the WTP to prevent that decrease in H will be small, not exceeding the cost to the person of the defensive action. Similarly, WTP to obtain an improvement in H will not exceed the cost to the individual of the defensive action to obtain the improvement.

Another expression for marginal WTP for potential changes in H can be derived from Equation (2-10), using the first order condition for D.

$$WTP_H - w*Ts_H + Qm*M_H + Qd*D_H + a*U_H \quad (2\text{-}11)$$

where the subscripts denote partial derivatives.

The first term is the opportunity cost of the change in time spent sick associated with a change in H, the second term is the change in medical expenditures associated with the change in H, the third term is the change in defensive expenditures associated with the change in H, and the fourth term is the dollar equivalent of the direct change in utility (i.e., the pain and discomfort) associated with the change in H. The dollar equivalent of a unit change in U (i.e., the marginal utility of a one-unit change in income) is represented by (a) in the fourth term.

The utility maximization conditions of the model suggest that when there is a change in pollution, the individual will adjust the allocation of his resources so as to minimize any adverse effect on utility, or maximize any advantageous effect. For example, if pollution increases, the individual may choose to completely offset the effects on his health by increasing defensive expenditures only if the resulting reduction in income available for other goods (X) reduces utility less than the decrease in utility that would have occurred from the decrease in H. The individual will, of course, be constrained by his ability to affect health with defensive expenditures. An expression for marginal WTP for a change in pollution (p), similar to Equation (2-11), can be derived from the model. This expression can be written as follows where, for example, dM/dP is the total change in medical expenditures as a result of the change in p after the individual has adjusted to maximize utility.

$$WTP_P = w^* (dts/dP) + Qm^*(dM/dp) + Qd^*(dD/dp) + a^*(-dU/dP) \quad (2\text{-}12)$$

Barrington and Portney (1987) use this derived expression for WTP for changes in pollution to argue that under certain reasonable assumptions, cost of illness estimates for changes in pollution that include income lost and medical expenditures can be expected to be a lower bound on WTP. Income lost due to time spent sick will be less than or equal to the first term, which is all time spent sick multiplied by the wage rate. Medical expenditures are equivalent to the second term. Cost of illness will be less than WTP as long as the third and fourth terms are non-negative for an increase, in pollution. This requires the assumption that the relationships in the model are such that when pollution increases, the new equilibrium level of health is the same or lower and that defensive efforts stay the same or increase. This assumption may not be correct in every instance. The analysis by Courant and Porter (1981) suggests that it is at least conceivable that the health production function and utility maximization conditions of the model are such that when pollution increases, health increases.

CHAPTER 3. METHODS

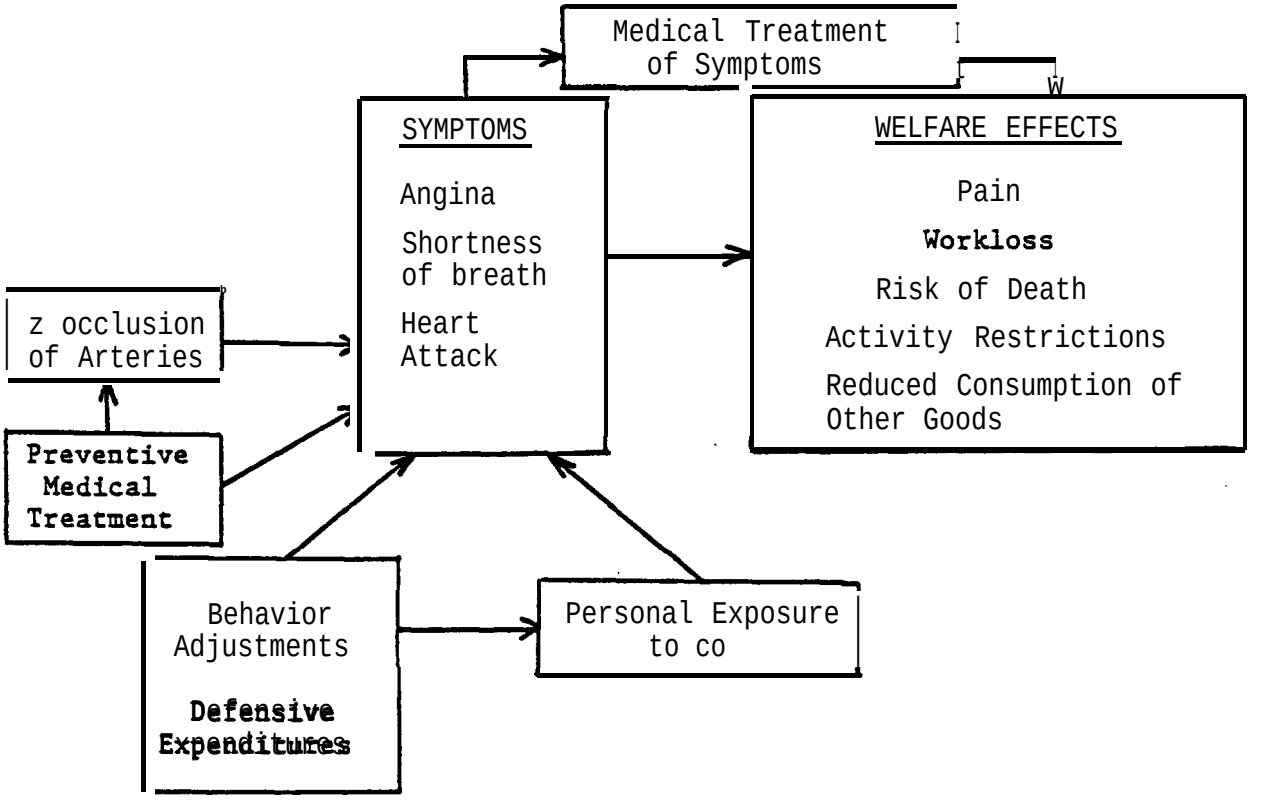
3.1 Questionnaire Development

The primary purpose of the study was to develop the means to estimate the value of changes in angina symptoms. Part of this work involved developing and testing a survey instrument for collecting information from IHD patients that would be useful in evaluating the effects of CO on angina symptoms. The study focused on the evaluation of changes in angina symptoms, whatever the underlying cause, and the effect of CO exposure was separately factored into the health production function (Equation 2-3). Figure 3.1-1 shows an expansion of the health/behavior model presented in the previous section as it is applied to the IHD patient with angina. This model guided the choice of measures and items in the survey instrument. Subject and interviewer versions of the questionnaire are included in Appendix 2.

The survey instrument combined several different approaches to examine the welfare implications of changes in angina symptoms for IHD patients. These included cost of illness, defensive activities, and contingent valuation estimates of WTP. The model presented in the previous section suggests that a comprehensive approach for evaluating the effects of CO on angina symptoms would involve the specification and estimation of Equations 2-3 and 2-4. However, estimating this system of equations is difficult due to the complexities of the relationships involved. A larger sample size than that obtained for this test of the developed instrument is needed for a more satisfactory evaluation of this approach.

Throughout the questionnaire we have attempted to keep questions about angina symptoms in the context of the overall effects of having IHD on the

Figure 3.1-1. Linkage between expenditures and health for IHD patients



patients' lives. It was uncertain at the outset whether the subjects would be able to isolate angina symptoms from other concerns, especially concern about potential heart attacks. Such a perceived (whether real or not) association may be very significant in determining how a subject reacts to questions about angina and may mean that isolated consideration of angina symptoms is inappropriate.

3.1.1 cost of Illness

To develop an estimate of annual medical costs, the survey instrument collected detailed information on medical treatment associated with IHD obtained in the past year. Because most of our subjects were VA patients, or had some other medical insurance, little information could be obtained about actual costs. A different sample of patients might produce a different result.

Even though the extensive insurance coverage for this sample meant that few of the medical costs were borne by the individual, medical cost estimates are still useful. Medical costs that are not borne by the individual would not be expected to be reflected in the estimates of WTP derived from the individual's behavior or from direct WTP questions. Medical costs are, however, a cost to society and should be considered in a comprehensive analysis of the effects of a policy that would result in changes in IHD symptoms . Medical care information is also important for the health production function estimation, and in many cases should be considered a defensive effort,

The costs of medical treatment were estimated using each individual's self report of treatment. Treatment scenarios were assembled under the

guidance of a staff cardiologist from the UC Irvine Medical Center. The costs of a typical emergency room visit, hospitalization for complaint of chest pain or myocardial infarction, or surgical procedures were estimated using accounting records furnished by UC Imine Medical Center. Data on the costs of each procedure could not be obtained for the VA Medical Center. Therefore, without access to accounting records for each subject, the costs of medical treatment derived in this study represent the best estimate based upon reasonable scenarios and the fee-for-service data of one regional medical center.

The survey also included questions on work loss due to angina and other IHD symptoms. Patients currently working were asked about work loss days and paid sick leave. Subjects younger than retirement age who were not working were asked if they had ceased work because of IHD and what they had earned previously, This allowed quantification of income lost due to IHD.

3.1.2 Defensive Activities and Expenditures

The subjects were next asked a series of questions regarding expenditures undertaken to avoid or reduce angina symptoms. These questions were intended to allow evaluation of Equation 2-10. Additionally, they extended medical care information to nonmedical activities that may be important in the overall status of the individual's health. Finally, these questions help those respondents with expenditures focus upon their own revealed willingness to pay to reduce angina prior to the direct willingness to pay questions.

One series of questions probed whether the individual hired help for chores he would otherwise do on his own, such as lawn mowing and house cleaning. Subjects were asked to identify the type of help hired, if any, and

whether the hiring was primarily motivated by their heart condition. This inquiry served to identify joint benefits. Expenditures were included in this part of the analysis only if the subject said that he would prefer to do the work himself if his health permitted. The subject was then asked to estimate the number of angina episodes he believed he avoided by making the expenditure. He was asked whether other health concerns, such as heart attack risks, might also motivate the expenditure. This provided an estimate of H_D from Equation 2-10, based on the perceptions of the subject.

In addition, subjects were asked to list all expenditures undertaken to avoid angina, to develop a total defensive expenditure estimate for each subject. Some descriptive information about changes made in activities due to the heart problem was also obtained.

3.1.3 Direct WTP Questions

Estimation of WTP was approached by directly asking questions about the amounts subjects would be willing to pay to avoid an increase in angina symptoms, Prior to these questions, subjects were asked to describe recent typical, severe, and mild angina episodes. They were also asked to rate the significance of various aspects of the problems associated with angina, including pain, medical costs, lost income, and worry about heart attacks. These questions gave better characterization of the impact of angina symptoms on the patient, and prompted the subject to think about how the symptoms affected him.

Two types of WTP questions were asked. Close-ended questions asked whether subjects would pay certain given dollar amounts to prevent a specific increase in angina, these were followed by open-ended questions in which

subjects were asked to give a dollar estimate of the maximum amount they would be willing to pay to prevent the hypothesized increase in angina. The decision to use both types of WTP questions was made following the preliminary interviews, in which subjects found the open-ended WTP questions alone difficult to answer. It was easier to give a dollar amount after being asked to consider a few specific amounts suggested by the interviewer. It is possible that the amounts suggested in the close-ended questions were leading the responses to the open-ended question. This problem is addressed in the analysis, in Section 3.4 of this chapter.

To discuss whether the WTP amount per episode would change if different numbers of episodes were anticipated, approximately half the subjects were asked about an angina increase of four episodes per month, and the other half were asked about eight episodes per month. The numbers of episodes were selected as small enough to be potentially realistic with respect to the impacts of air pollution and large enough to be significant to the individual. Since some subjects no longer had active angina, and therefore had no interest in decreasing their symptoms, all subjects were asked about a potential increase rather than decrease in angina symptoms. It was also considered more realistic for most IHD patients to consider an increase rather than decrease in symptoms as they had already made all the health improvement they could through surgery, treatments, and lifestyle changes. This question is also policy relevant because IHD tends to be a progressive disease with symptoms increasing over time. Reductions in air pollution might prevent angina symptoms from increasing as much as they would otherwise have for some patients. The hypothesized payment vehicle was a medication that would prevent an increase in angina, but that would not be covered by insurance.

Follow-up questions were used to probe refusals, zeros, and responses of very large WTP amounts . Interviewers also recorded comments offered by the subjects while responding to these questions.

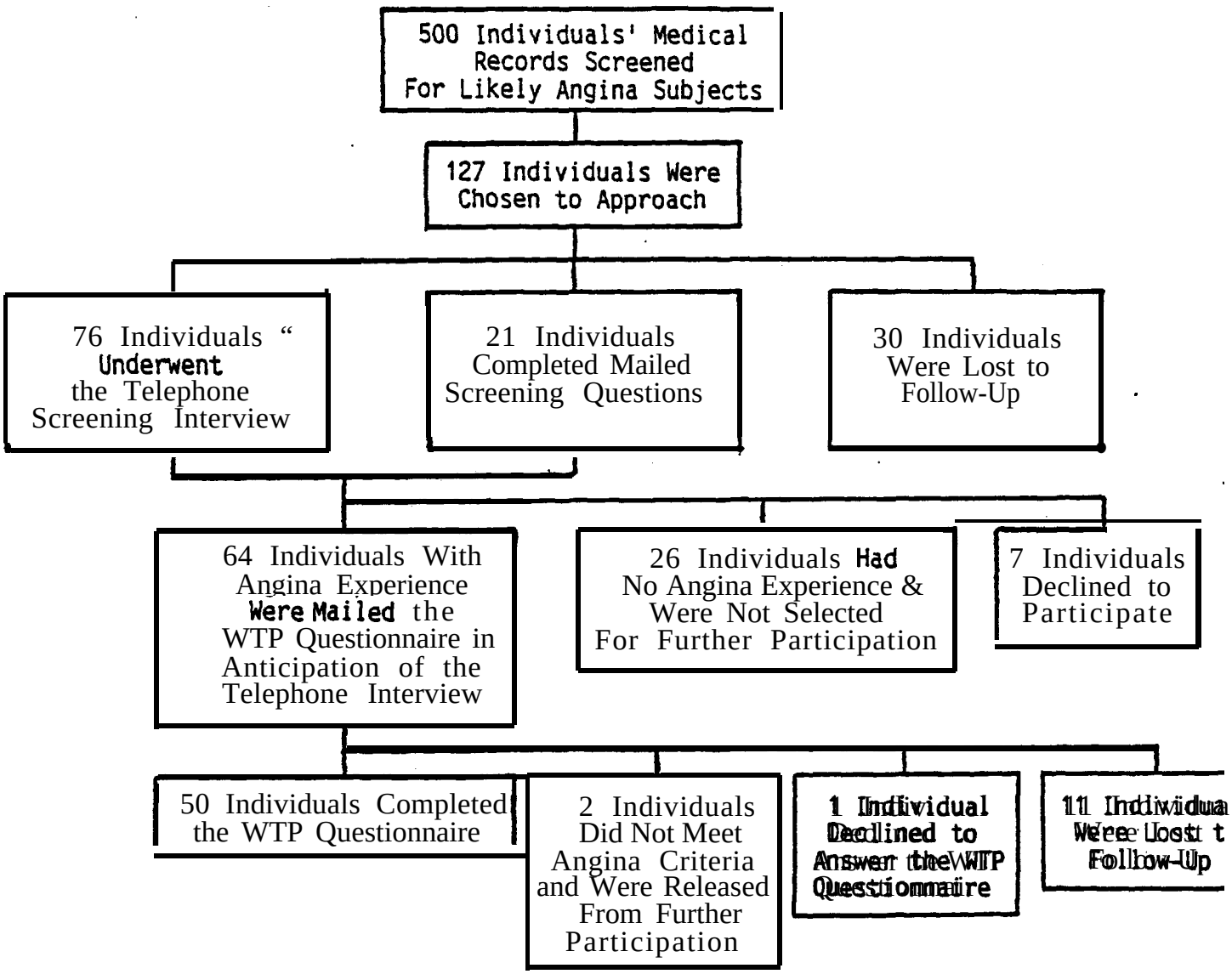
3.1.4 Health Production Function

Given the small sample size of this study, we did not attempt to estimate a health production function; pertinent information was obtained, however, to contribute to such an estimation with a larger study sample. This information included medical history, attitudes toward health risks and angina, and information that would help assess potential exposure to CO.

3.2 Panel Selection

Medical records from the UC Irvine Medical Center and the Long Beach VA Medical Center were reviewed to identify potential participants (Figure 3.2-1). A subject pool of 500 men was identified for earlier community exposure monitoring and clinical studies on the health effects of CO (California Air Resources Board projects performed by UC Irvine). Of this group, 127 men with a history of chest pain and physician diagnosis of angina pectoris were targeted to confirm their angina experience and solicit participation in the Study. Seventy-six men were successfully contacted by telephone and completed the initial screening interview (Appendix 1). A modified version of the Rose Questionnaire (Rose et al., 1977) was administered to each subject to identify individuals who had experienced angina symptoms within the previous 12 months. The Rose Questionnaire has demonstrated a sensitivity of 81 percent and a specificity of 97 percent in similar field applications (Heyden et al.,

Figure 3.2-1. Angina subject selection and disposition



1971). If a subject's answers" to this screening interview identified' him as having experienced the complex of symptoms associated with angina pectoris within the last year, he was asked if he would be willing to participate in a longer inteniew regarding his angina and how it affected his lifestyle. Targets who could not be reached by telephone were contacted by mail and asked to complete an abbreviated form of the initial telephone interview to confirm a history of angina. No compensation was offered for participation in the Study.

Of the 127 individuals with angina experience, 64 were identified as having recent angina symptoms and were mailed the Subject "Version Questionnaire to complete and have available as a visual guide during the telephone interview. Telephone interview contact was attempted seven to 10 days later. (See cover letter, Appendix 2). Of the 64 potential subjects, 50 completed the interview; 11 could not be contacted by telephone and were lost to follow-up; two did not qualify and were released from further participation; and one declined to answer the questions, judging them to be of a highly personal nature.

Characteristics of the Sample

The 50 men participating in the study represent a wide range of angina experience (Table 3.2-l). Forty-three subjects were currently experiencing angina with a mean frequency of one episode per week, with a discomfort level described as generally being mild to moderate. Information on the length of time that the subjects had experienced angina symptoms was not collected. However, all subjects' angina experience was at least two years, corresponding to the age of hospital medical records from which the subjects were

Table 3.2-1. Characteristics of research subjects used to evaluated the survey instrument

Characteristic	Mean Value	Frequency or Range
Current Angina		43/50
Former Angina		7/50
Experienced a Heart Attack		34/50
Angina Frequency	l/Week	< 1/mo to > 3/day
Angina Severity	Mild to moderate	No to very severe discomfort
Coronary Artery Bypass Surgery		23/50
VA Health Insurance		39/50
Private Health Insurance		15/50
MediCare		22/50
HMO Program		3/50
MediCal		7/50
Employed		15/50
Household Income	$22,021	< $4,999 to > $60,000
Age	61.5	44-83
Married		39/50
Number in Household	2.4	1 to 5
Education	Completed High School	3rd grade to Postgraduate
Ancestral Origin		43/50 White 4/50 Latino 2/50 Black 1/50 Indian
Current Smoker		5/50
Former Smoker		37/50

selected. Seven subjects no longer experienced angina and largely attributed relief to bypass surgery. Thirty-four subjects had experienced at least one heart attack. The median time since last heart attack was two to three years. Twenty-three subjects had undergone coronary artery bypass graft surgery.

Thirty-nine of the 50 subjects were eligible to receive health services from the Veterans Administration. The majority of subjects supplemented their VA coverage with private insurance or MediCare. In general, subjects had complete coverage for physician office charges and emergency room and hospitalization expenses.

Fifteen subjects were currently employed. The household income of subjects ranged from less than $4,999 to greater than $60,000, with a mean of $22,000.

The age of the subjects ranged from 44 to 83 years, with a mean of 61.5 years.

Thirty-nine of the subjects were not currently smoking tobacco and of this group, eight had never smoked.

Thirty-four of the 50 subjects had participated in an earlier research project conducted by UC Irvine measuring personal exposure to CO in the community, and 14 subjects had participated in clinical studies examining the effects of CO on the heart under exercise stress.

3.3 Sampling Procedures

All subjects lived in the greater Los Angeles area. Interviews were conducted between February 20 and July 1, 1986. The four earliest interviews, conducted in February, served as pilot interviews. Based upon

responses, the questionnaire was edited. The survey of the main sample began in April with the majority of the interviews being conducted in May and June. Typically, several calls were required to schedule a convenient time to conduct the 45-minute interview. Subjects often requested additional time to review the questions prior to the interview.

Three interviewers were used in the study; each read dialogue and questions from the Interviewer Version Questionnaire. Telephone headsets were used to free the interviewer's hands and facilitate accurate recording of the responses. Average interview length was approximately 40 minutes. Immediately after concluding the interview, an additional 20 minutes was needed to review and edit interviewer notations, and check for completeness of questionnaire information and tracking documentation.

The number of episodes and the dollar amounts assigned to the closed-ended willingness-to-pay question (Question 32, see page 13, Subject Version of Questionnaire, Appendix 1) were randomly assigned to subjects according to the Treatment Code schedule in Table 3.3-1. Treatments 1 through 10 were randomly assigned in the first mailing of questionnaires to 20 subjects in early April, 1986. After completing 15 of the 20 interviews, ERC and UC Irvine reviewed responses and saw that nearly all subjects said they would pay the highest amount suggested. Indeed, the response to the subsequent open-ended question was typically a higher sum than the highest amount suggested in the close-ended question. A revised treatment schedule was formulated on May 8, 1986; treatments 21 through 28, was used for the remainder of the subject pool (Table 3.3-l).

An additional adjustment was made at this time. Relative to Questions 32 and 33, a high rate of refusals and very high dollar responses were observed for Questions 30a and 30b. This suggested that without the more detailed

Table 3.3-1. Schedule of dollar amounts (treatments) used in close-ended willingness-to-pay question (Question 32)

TREATMENTS	EPISODES	DOLLAR AMOUNTS		
1	4	5	50	200
2	8	5	50	200
3	4	10	25	50
4	8	10	25	50
5	4	25	50	100
6	8	25	50	100
7	4	50	100	200
8	8	50	100	200
9	4	100	200	400
10	8	100	200	400
21	4	10	50	200
22	8	10	50	200
23	4	25	100	300
24	8	25	100	300
25	4	50	200	400
26	8	50	200	400
27	4	100	500	1000
28	8	100	400	1000

Treatments 1-10 were randomly assigned in the first mailing of questionnaires to twenty subjects in early April 1986. After completing 15 of the 20 Interviews, ERC and UCI reviewed the success of the dollar amounts in bracketing the range of observed responses, and a revised treatment schedule was formulated on May 8, 1986. The revised schedule, treatments 21-28, was used for the remainder of the subject pool.

Table 3.3-1 cont.

An additional adjustment was made at the time of this revision. It was decided that Questions 30a and 30b should be asked out of sequence, after completing Question 32 and 33. A third digit was added to the Treatment Code to indicate this change of sequence. If Questions 30a and 30b were asked in sequence after completing the line of inquiry on the "typical recent" angina episode, the third digit of the treatment code was assigned a "l." If Question 30a and 30b were asked after the willingness-to-pay Questions 32 and 33, then the third digit of the treatment codes was assigned a "2." For example, Treatment Code 242 represents Treatment 24 (eight episodes, $25, $100, and $300) and Questions 30a and 30b were asked after completing Questions 32 and 33. (Note that this change in sequence was instituted immediately and several individuals in the first treatment schedule were interviewed using the adjusted sequence of waiting to ask Questions 30a and 30b).

context given far the WTP question, subjects had more difficulty making a decision. It was therefore decided that sequencing of Questions 30a and 30b (asking for the maximum dollar amount one was willing to pay to avoid one or two typical angina episodes) should follow completion of Questions 32 and 33, which were introduced by a more careful explanation of the payment situation. A third digit was added to the Treatment Code to indicate this change of' sequence (Table 3.3-l). If Questions 30a and 30b were asked in the original sequence, the third digit of the Treatment Code became "1." If Questions 30a and 30b were asked after the willingness-to-pay Questions 32 and 33, then the third digit of the Treatment Code became "2.". For example, Treatment Code 242 represents Treatment 24 (eight episodes--$25, $100, and $300) and Questions 30a and 30b were asked after completing Questions 32 and 33.

3.4 Data Analysis

Questionnaire data were coded according to the format described in Appendix 3. Open-ended responses and research subjects' comments were transcribed and assembled by question number (Appendix 4). Data was entered into an IBM personal computer using dBASE III software. Accuracy of the coding and data entry was verified by independent observers. Data files were converted to standard ASCII format, written to floppy diskettes, and distributed among the co-investigators. Specific statistical analyses are described within each section of the Results and Discussion.

CHAPTER 4. RESULTS AND DISCUSSION

4.1 Cost of Illness

4.1.1 Medical Expenditures

Medical expenses associated with anginal pain, and more generally the IHD condition, were estimated for each subject (See Appendix 4). Responses to questions on yearly insurance premiums paid (Question 9b), mileage to physician's office (Question 10), frequency of office visits (Questions 11b and 12a), costs of emergency room visits (Question 15b), hospitalizations (Question 16), medical treatment programs (Question 17), and medications (Question 14) were tabulated.

Annual health insurance premiums ranged from $0 to $1002 with a mean of $201 per subject. Twenty-three subjects made no expenditure for health insurance and largely relied upon coverage from the VA. Nineteen subjects receiving VA health care benefits chose to supplement that coverage with MediCare. Annual MediCare premiums cost $186. Fifteen subjects were covered by private medical insurance; ten of these subjects also received VA health benefits. For those subjects purchasing private insurance, premiums ranged from $0 to $822, with a mean of $365 per subject.

One-way mileage to the physician's office for a regular checkup ranged from 1 to 45 miles, with a mean of 14 miles. Yearly expenditures for travel to the physician's office were estimated from the number of regular office visits (Question ha), additional office visits due to angina symptoms (Question 12), round trip mileage (Question 10), and an assumption of personal motor vehicle expense of $0.205 per mile. Annual mileage expenses ranged from $0 to $226, with a mean of $38 per subject.

In general, the expense of physician office visits, emergency room visits, and hospitalizations was completely covered by the subjects' health insurance benefits. Of 44 subjects reporting visits to their physician during the previous year, nine reported out-of-pocket expenditures ranging from $12 to $192; the mean annual office visit expense paid by the subject across the 44 subjects was $22. No out-of-pocket expenses were incurred by the 13 subjects reporting emergency room visits during the previous year. of 15 subjects experiencing overnight hospitalizations during the year, two reported out-of-pocket expenses of $1,000 and $380, respectively.

Medication expenses were not as well covered by insurance as health services. Fourteen subjects reported paying $12 to $1440 during the previous year for heart related medications. The group of 36 subjects whose medication expenses were paid in total by health insurance was largely composed of recipients of VA benefits. Across the sample of 50 individuals, the mean annual out-of-pocket medication cost averaged $144 per subject.

The sum of all expenses paid by the subject in the aforementioned expense categories, omitting health insurance premiums, provided an estimate of the yearly expenditures made by each subject for ischemic heart disease medical care. Personal annual medical expenditures ranged from $0 to $2610, with a mean of $256 per subject across all 50 subjects. Health insurance costs were omitted from this SUM because insurance provided care for a broad spectrum of medical problems, not just ischemic heart disease.

The societal costs of health services for this group are substantial. Societal costs are defined as the expenditures made by insurance companies, or the government in the case of the VA, to provide care. It is important to note that "societal" costs do not include the out-of-pocket expenses incurred by the individual. Societal costs were estimated from medication dosages and

the types of me-dical services used by the subjects. The cost of medications was estimated using the mean price of generic and name brand prescription dngs distributed by a privately-owned pharmacy and by a major chain pharmacy (Appendix 4). The cost of health services (Appendix 4) was estimated using fee schedules from the UC Irvine Medical Center and the Report on Medical Fees in Southern California (1986). Dennis M. Davidson, MD., a UC Irvine cardiologist, and the UC Irvine Medical Center accounting staff assisted in assembling scenarios of the services likely to be rendered during typical " emergency room visits and hospital stays. The estimates derived from these for the cost of hospitalization reflect conservative (i.e., low) estimates of the types and numbers of procedures likely to be associated with the subject's generalized description of the event (e.g., "'emergency room visit for chest pain, ' 'angioplasty, ' '3-day hospital stay for heart tests'"). It is important to note that professional fees for services are not reflected in these estimates (e.g., anesthesiologist's fee for bypass surgery). It was sometimes possible to use a subject's report of the cost to the insurance company. However, this strategy could only be used in a few instances as the sample was predominantly composed of VA patients who did not receive any billing information. For reasons of patient confidentiality, VA accounting records could not be accessed for estimating cost of services.

The societal costs of medication for the 50 subjects ranged from $0 to $2=429 per year, with a mean of $676. Likewise, the societal cost of office visits ranged from $0 to $3780 per year, with a corresponding mean of $576 per subject. The cost to society of the emergency room visits made by 13 subjects ranged from $77 to $1364 per year, with a mean of $342 per subject. Fifteen subjects had been hospitalized during the previous year. The annual cost of hospitalization, including surgical procedures, for these 15 subjects was

estimated to range from $1630 to $33,435, with a mean of $10,607 per subject. These costs include the major medical events of three coronary artery bypass graft surgeries (CABG) and two angioplasty (PTCA) procedures. In summary, annual medical costs to society ranged from $0 to $34,963, with a mean of $452.3 per subject across all 50 subjects. This result suggests that the societal burden of angina-related medical expenses is at least ten times that of the personal expenses incurred in this sample of IHD subjects.

4.1.2 Workloss Due to Angina and the IHD Condition

Information was obtained from the subjects concerning the effects of angina on their employment status and time lost from current jobs. This information is summarized in Table 4.1-1. Table 4.1-2 contains definitions for variables used in these calculations. Dollar estimates were developed for three types of work loss: (1) days lost from current jobs due to angina, (2) additional work days desired for those working less than they would like due to angina, and (3) wages lost by subjects who were compelled to give up working due to angina. Dollar values were based on the wages reported by the subjects. For two subjects who refused to give their wages, estimates were made based upon their reported occupations and hours worked.

Fifteen of the subjects (30 percent of the total sample) reported being currently employed. These 15 subjects worked an average of 35 hours per week and earned an average of $19,400 annually.

Of the 15 employed subjects in the sample, six subjects had missed some days from their regular work schedule in the past year due to angina. The 15 employed subjects missed an average of four days from work in the past year due to angina, incurring an average social cost of $347 in lost productivity

Table 4.1-1. Workloss due to angina.

	Employed Subjects with Some Workloss Due to Angina	Average Annual Workloss for Employed Subjects (N = 15)	Average Annual Wage Lost for Enployed Subjects (N = 15)
15 Subjects Employed (30% of Total Sample)	6	4 days	$ 347

	Employed Subjects Working Less Than Desired	Average Annual Additional Work Days Desired (N = 6)	Average Annual Wage Lost for Employed Subjects (N = 6)
15 Subjects Employed (30% of Total Sample)	6	108 days	$3973

	Average Annual Wage Lost for Subjects Not Working (N = 13)
13 Subjects Not Working Due to Angina (37% of Non-Working Subjects)	$34615

Table 4.1-2. Definitions of variables used to compute wages lost from current employment due to angina

SWLD	Wages lost to subject due to days lost from current employment If Q21DSKLV - 1, then SWLD = Q21CMISS * HRWAGE * 8 If Q21DSKLV - 2, then SWLD = Q21DDAYS * HRWAGE * 8
TWLD	Total wages lost due to days lost from current employment TWLD = Q21CMISS * HRWAGE * 8
WKRED	Wages lost to currently employed due to being unable to work as much as desired If Q21FFEWER- 1, then WKRED = 0 If Q21FFEWER - 2, then WKRED = (Q21FLIKE - Q21AHRS) * HRWAGE * 52
JOBLOSS	Wages lost due to having quit working due to angina JOBLOSS - QA21CINC evaluated at the midpoint of the reported range in dollars
SWKLOSS	Workloss in all three categories incurred by subject SWKLOSS = SWLD + WKRED + JOBLOSS
TWKLOSS	Total workloss in all three categories TWKLOSS = TWLD + WKRED + JOBLOSS
HRWAGE	Hourly wage for currently employed HRWAGE =-Q21GINC/(Q21AHRS * 52), where Q21GINC is evaluated at the midpoint of the reported range in dollars For Subject 6, an electronic technician working 62 hours/week estimated annual income was $35,000 For Subject 16, a clerical employee working 20 hours/week estimated annual income was $6,000

Additional notes:

1. For Subject 72, Q21DDAYS was recoded from blank to 0 because the subject did have paid sick leave, but did not miss any days due to angina.

2. For Subject 107, Q21DCOVR was recoded from 2 to 1 due to a previous coding error.

3. WKRED was actually calculated on responses from 5 subjects since Subject 16 said he would like to work more but did not give any estimate of how much more.

measured by the wage rate. Only one of the subjects who missed work due to angina had any paid sick leave, therefore the average wage loss incurred by the subjects themselves ($336) was very close to the total wage loss.

Of the 15 employed subjects, six subjects said they would have liked to work more, but were unable to because of angina. These six subjects currently worked an average of 20 hours per week and would have liked to work an average of 40 hours per week. For these six subjects the average annual wage loss caused by working less hours than desired was $3973. We assume that this work loss is in addition to occasional sick days lost from a regular work schedule and therefore add these two estimates to obtain total losses for employed subjects. One subject also said he had changed jobs due to angina and had incurred a reduction in income due to this job change. A dollar estimate of this loss was not obtained.

Of the 35 non-employed subjects, 13 said they had ceased to work or had taken an early retirement in the last five years due" to their angina. These subjects had earned an average of $34,615 annually before they ceased working. Assuming that all these subjects would have been working this past year if they could, their previous annual wage was used as an estimate of the annual loss due to being unable to work. To allow more precision in this estimate it would have been preferable to also ask the subjects if they would be working now if they could. Also, disability payments might be mitigating some of this lost income for the subjects causing our estimate of loss to the subject to be overestimated. This does not, however, affect the total loss incurred by society as a whole.

4.1.3 Annual Cost of Illness for Ischemic Heart Disease

The medical expenditures (due to IHD) data in Section 4.1.1 was combined with the income lost due to angina (from Section 4.1.2) to obtain a total cost of illness estimate. The mean annual medical expense and income lost incurred by the individual was $9,833 for this group of subjects, ranging from $0 to $65,374. The mean cost incurred by the individual and others (insurance companies, VA, etc.) per year due to ischemic heart disease was $14,359, ranging from $0 to $67,176.

The focus of this study is the potential effect of changes in CO exposure on the frequency of angina pains. To evaluate the potential welfare impact of changes in CO exposure, we are therefore interested in the effect of a marginal change in angina pain on costs incurred. Regression analysis was conducted relating cost of illness measures to characteristics of the individual illness to determine whether a marginal cost per angina episode could be estimated. The results are shown in Table 4.1-3. Potential explanatory variables included were whether the subject had a heart attack in the previous year (MIYR1), whether the subject had bypass surgery in the previous year (SURGYR1), current monthly angina frequency (MONFREQC), and income. Regressions were estimated with four different cost of illness variables: (1) medical expenses incurredby the subject (MEDSELF), (2) total medical expenses (MEDTOT), (3) medical expenses and income loss incurred by the subject (COISELF), and (4) total medical expenses and income lost (COITOT).

The results indicate that very little of the variation in these cost of illness estimates across this sample is explained by these variables, and angina frequency is not statistically significant in any of the regressions.

Table 4.1-3. Regression analysis relating cost of illness and Individual characteristics

Analysis of Variance

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB > F
Dep Variable: MEDSELF					
MODEL	4	502001.75970	125500.43992	0.554	0.6969
ERROR	42	9507502.71	226369.11210		
C TOTAL	46	10009504.47			
ROOT MSE		475.7826	R-SQUARE	0.0502	
DEP MEAN		262.1064	ADJ R-SQ	-0.0403	
C*V.		18105227			

Parameter Estimates

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T For Ho: PARAMETER = 0	PROB > |T|
INTERCEP	1	75.76267837	154.94207071	0.489	0.6274
MIYR1	1	25.38154878	199.90387347	0.127	0.8996
SURGYR 1	1	-57.7657	290.00827743	-0.199	0.8431
MONFREQC	1	2.61060003	3.24238982	0.805	0.4253
Q43HINCM	1	0.68142915	0.48939933	1.392	0.1711

cont.

D p V
MEDTOT

Analysis of Variance

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB > F
MODEL	4	2068004458	517001114.57	26.432	0.0001′
ERROR	42	821520312.99	19560007.45		
C TOTAL	46	2889524771			

ROOT MSE	4422.67	R-SQUARE	0 . 7 1 5 7
DEP MEAN	4921.191	ADJ R-SQ	0.6886
C.V.	89.8699		

Parameter Estimates

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T For Ho: PARAMETER = 0	PROB > |T|
INTERCEP	1	2827.35654	1440.27453	1.963	0.0563
MIYR1	1	7026.69540	1858.22002	3.781	0.0005
SURGYR1	1	23400.84420	2695.79161	8.681	0.0001
MONFREQC	1	-20.131	30.13985452	-0.668	0.5078
Q43HINCM	1	-0.75965	4.54924470	-0.167	0.8682

Table 4.1-3 cont.

Analysis of Variance

Dep Variable: COISELF

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB > F
MODEL	4	704973692.90	176243423.23	0.483	0.7483
ERROR	42	15336119332	365145698.38		
C TOTAL	46	16041093025			

ROOT MSE	19108.79	R-SQUARE	0.439
DEP 'MEAN	10445.28	ADJ R-SQ	-0.071
C.V.	182.9419"		

Parameter Estimates

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T For Ho: PARAMETER = 0	PROB > |T|
INTERCEP	1	6366.09593	6222.91496	1.023	0.3122
MIYR1	1	-4407.81	8028.70905	-0.549	0.5859
SURGYR1	1	5531.15387	11647.55861	0.475	0.6373
MONFREQC	1	155.39545313	130.22361230	1.193	0.2395
Q43HINCM	1	10.1189970	19.65567146	0.515	0.6094

D
O OT

Analysis of Variance

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB > F
MODEL	4	2552325422	638081355.57	1.619	0.1873
ERROR	42	16552119378	394098080.44		
C TOTAL	46	I9104448o1			

ROOT MSE	19851.9	R-SQUARE	0.1336
DEP MEAN	15104.36	ADJ R-SQ	0.0511
C.V.	131.4316		

Parameter Estimates

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T For Ho: PARAMETER = 0	PROB > |T|
INTERCEP	1	9117.68980	6464.91668	1.410	0.1658
MIYR1	1	2593.50550	8340.93593	0.311	0.7574
SURGYR1	1	28989.76376	12100.51822	2.396	0.0211
MONFREQC	1	132.65382029	135.28785265	0.981	0.3324
Q43HINCM	1	8.67792023	20.42005699	0.425	0.6730

There is a significant relationship between total medical expenses and heart attack or bypass surgery in the past year. In the cost of illness regressions the angina frequency coefficients are positive and might be statistically significant in a larger sample.

Additional information on out-of-pocket costs associated specifically with angina episodes was obtained in the series of questions asked about the subject's most recent angina episode. In response to the question, "If there was any monetary cost to you due to this episode, can you estimate how much it was ?" The vast majority of the subjects responded that there was no cost other than the few cents for a nitro tablet. One subject said that there was a cost due to time missed from work. A very serious angina episode might be more likely to cause the patient to seek immediate medical attention, "but only a small percentage of episodes would be this serious. A larger sample might find some out-of-pocket cost significantly different from zero with a question like this, but we recommend that the regression approach previously presented also be applied. It is possible that a higher frequency of angina is associated with additional costs (e.g., more medical check-ups) that cannot be easily linked to a specific episode.

These results suggest that the incremental dollar cost associated with a marginal change in angina frequency could be expected to be relatively insignificant. This means that a welfare measure based on cost of illness only would reflect minimal impact on a subject's welfare due to a marginal change in angina frequency. This result, which is not substantiated by other evidence provided by the respondents, makes it all the more important to consider other welfare measures such as willingness to pay and averting expenditures estimates;

4.2 Willingness to Pay

4.2.1 Introduction

A variety of questions were used to obtain an overall picture of the potential effects of changes in angina severity or frequency. Subjects were first asked to rate eight possible effects of an increase in angina on a scale of "bothersomeness" (Question 31). The aggregate rankings of these effects are given in Section 4.2.2. Subjects were also asked whether or not they would be willing to pay specific dollar amounts to prevent a specific increase in angina episodes (Question 32). The analysis of the responses to these close-ended willingness-to-pay questions is in Section 4.2.4. Finally, subjects were asked to specify dollar amounts that they would be willing to pay to prevent a specific increase in angina. Willingness to pay to prevent one and two episodes (Questions 30 and 30b) is analyzed in Section 4.2.3. Willingness to pay to prevent four or eight episodes (Question 33) is analyzed in Section 4.2.5. Special focus is placed on answers of $0 or very large dollar amounts. The relationship of a person's willingness to pay amount with his other survey responses is analyzed in Section 4.2.6.

4.2.2 Rankings of Effects of Increased Angina

For Question 31, subjects were asked to place eight potential effects of an increase in angina on a scale of 1 to 10, with 1 being the least bothersome and 10 being the most bothersome. Table 4.2-1 shows the mean rating for each category. In some cases the subjects responded that a particular category was not relevant to them. A zero rating was used in these calculations when the

Table 4.2-1. Rating and share means of potential effects of an increase in angina. Percentage shares for each effect are calculated using the total number of points given by each subject for all eight categories, thus providing a normalized measure of bothersomeness (Question 31)

Answers to question: Most bothersome effects you may experience if your angina worsened:

		Rating (1 to 10)*		Share (%)	
		Mean	Std. Error of Mean	Mean	Std. Error of Mean
a.	More medical treatment expenses.	3.28	.44	.066	.008
b.	Less ability to earn income.	3.24	.53	.061	.009
c.	More non-medical expenses (such as paying for services)	3.98	.43	.083	.008
d.	More pain or discomfort.	7.84	.35	.181	.012
e.	Less ability to work at a job (for reasons other than income).	5.18	.57	.106	.011
f.	Less ability to do desired activities (recreation, chores, or work).	8.06	.31	.180	.008
g.	More concern to you about potential heart attack or bypass surgery.	7.12	.44	.155	.010
h.	More concern to you about worry or inconvenience to family and friends due to your health.	7.46	.42	.167	.011

*1 - least bothersome; 10 - most bothersome.

subject said the category was not relevant. This occurred most often with the income and job performance categories for the subjects who are not employed. It is important to note that these two categories might receive a higher rating if an improvement in angina were being considered rather than a deterioration, especially from subjects younger than retirement age who are not working due to their disease.

The mean ratings are all statistically significantly different except for (f) activity restriction and (d) pain. These two effects were rated as the most potentially bothersome, followed by (h) others' worry and (g) heart attack concern. Job satisfaction was next, followed by the three financial categories. Even though these subjects all had medical insurance, (a) medical expenses received a slightly higher rating than (b) ability to earn income. Ability to earn income may not be an important concern for many of the subjects who are beyond retirement age.

To adjust for possible differences in the subjects' use of the 1 to 10 scale, percentage shares for each category were calculated based on the total number of points given by each subject for all eight categories. The mean shares are also given in Table 4.2-1. The order is the same except that (f) activity restriction and (d) pain are reversed. The mean shares are all statistically significantly different except for (a) medical expenses and (b) ability to earn income.

Simple correlations among the shares were estimated to determine whether the ratings were related to one another. The significant correlations are shown in Table 4.2-2. There were three significant positive correlations: (b) ability to earn income with (e) job performance, (d) pain with (f) activity restriction, and (g) heart attack concern with (h) others' worry. The negative correlations suggest that the subjects who were more concerned

TABLE 4.2'2.

Paarson Correlat ions of "Bothersomeness Shares" and Personal Characteristics (Question 31)
(P in parentheses)

	a. Medical Expanses	b. Earning Ability	c. Defensive Expenses	d. Pain	e. Job Satisfaction	f. Activity Restriction	g. MI Concern	h. Others' Worry	Married	Household Income	uTP/income
a. More medical treatment expenses.						**-.33** (.02)					
b. Less ability to earn income.				-.30 (.04)	.46 (.00)	**-.34** (.02)	**-.24** (.10)	**-.41** (.00)	**-.31** (.03)		**.33** (.04)
c. Here non-medical expenses (such as paying for services).				**-.43** (.00)							**-.28** (.08)
d. More minor discomfort.						.30 (.03)					
e. Less ability to work at a job (for reasons other than income).							**-.47 (.00)**	**-.53** (.00)		**.24** (.10)	
f. Less ability to do desired activities (retreat ion, chores, or work).							**-.41 (.00)**				
g. More concern to you about potential heart attack or bypass surgery.								**.25 (.08)**			
h. More concern to you about worry or inconvenience to family and friends due to your health.									.40 **(.00)**		

about financial effects tended to be less concerned about pain, activity restriction, heart attack concern and others' worry.

Some significant correlations with other characteristics of the individuals are also shown in Table 4.2-2. Being married positively correlated with (h) others' worry and negatively correlated with (b) concern about ability to earn income. Annual household income is positively correlated with (e) job satisfaction, suggesting that subjects who earn more also obtain more general job satisfaction. Two of the shares were significantly related to willingness to pay to prevent an "increase in angina (Question 33) as a percent of household income: (b) concern about earning ability was positively related, and (c) concern about defensive expenses was negatively related. Characteristics that showed no significant relationship to any of the shares were number of heart attacks, income lost, total defensive expenses, current angina frequency, and willingness to pay to prevent an increase in angina (not as a percent of income).

The effects of subject characteristics on the ratings were further explored by examining the differences between mean shares for groups with different characteristics. These comparisons are shown in Table 4.2-3. Overall, these comparisons reveal differences in ratings that would be expected for subjects in different circumstances, and they support the conclusion that the subjects were able to distinguish among the categories of potential effects and give meaningful ratings to each.

4.2.3 WTP Responses for One or Two Isolated Episodes

Before any of the willingness to pay questions, the subjects were asked to describe a typical angina episode in terms of how it affected them as well

Table 4.2-3. Comparisons of shares to subject characteristics*

Comparison 1: What subjects do on days when expect more Angina (Question 19)

	Activity Restriction Share		
Group 1 - Makes no changes in activities (choice 1)	.148	(.068)	N=9
Group 2 - Avoid active recreation or physical exertion (choice 2 or 3)	.186	(.052)	N=29

Comparison 2: Cost of Illness

	Medical Expense + Income Shares	
Group 1 - Incur some COI (pay some medical expense or lost income)	.144 (.080)	N=25
Group 2 - No COI (100% insurance coverage and no lost income)	.111 (.088)	N=25

Comparison 3: Defensive Expenses

	Defensive Expense Share	
Group 1 - Incur some defensive expense	.097 (.059)	N=21
Group 2 - Incur no defensive expense	.074 (.074)	N=29

Comparison 4: Previous MI

	MI (and Surgery)Concern Share	
Group 1 - Have had no MI	.147 (.065)	N=16
Group 2 - Have had MI	.159 (.075)	N=34

Comparison 5: Previous Bypass Survery

	MI (and Surgery) Concern share	
Group 1 - Have had no bypass surgery	.169 (.072)	N=27
Group 2 - Have had bypass surgery	.139 (.069)	N-23

Comparison 6: Marital Status

	Others' Worry Concern	
Group 1 - Not married	.111 (.075)	N=11
Group 2 - Married	.183 (.069)	N=39

*Standard Error of Mean in Parentheses

as what they did to minimize the impact (Questions 22-29). Subjects were also asked to recall the single worst episode they had experienced, as well as a typical mild episode. One of the goals of this set of questions was to focus the subjects' thinking on the range of their experience with angina and how it affected them. Additionally, the questions provided some background information about angina from the subjects' point of view.

Subjects were asked what they would be willing to pay to avoid having a typical angina episode tomorrow (Question 30a). If subjects were willing to answer this question, they were also asked what they would be willing to pay to avoid two typical angina episodes in the next week (Question 30b). After the first set of 15 interviews were conducted, it appeared that subjects were having a harder time answering these questions than Questions 32 and 33. Concern was that these questions did not have sufficient introduction to make the willingness to pay question seem realistic, thus resulting in more refusals and potentially affecting the subsequent willingness to pay response. Questions 32 and 33 provided a more, detailed explanation about a hypothetical circumstance under which such a payment might occur.

In an attempt to address this concern, the questions on one and two isolated episodes (Questions 30a and 30b) were asked after Questions 32 and 33 in all subsequent interviews. The questions were deleted from the Subject Version questionnaires mailed to the second wave of subjects, and the interviewer simply read the questions over the phone after Questions 32 and 33 were completed.

Eight of the subjects had particular difficulty answering the questions concerning willingness to pay to prevent one and two episodes. Two of them refused to answer, two 'said they didn't know, and four said they would pay something but didn't know how much. In addition, two subjects gave extremely

high dollar responses. ($10,000 and $60,000 to prevent one episode), and four said that they would pay anything to prevent one episode. The two who gave the very high but non-infinite responses stuck to their answers when questioned by the interviewer as to whether that was what they meant. They said that they would be willing to pay anything they could, although they both gave lower estimates when asked Question 33 (both were asked about one and two episodes first). We interpret these very high bids as similar to the infinite responses, the difference being that these two subjects figured out what their income constraints might be. Half of these 14 "problem responses" occurred in the first 15 interviews, suggesting that the sequence change improved responses to this question but some problems remained.

Fourteen problematic responses were observed for Questions 30a and 30b. Seven of these were obtained from the 15 subjects who were asked the questions before Questions 32 and 33. The rate of problematic responses therefore declined somewhat after the order of the questions was changed (7/34 versus 7/15), but problems still occurred.

Table 4.2-4 shows a breakdown of the types of responses obtained for the three open-ended WTP questions. Overall, it appears that the subjects found it easier to answer Question 33 regarding the prevention of an increase in four or eight episodes per month for an indefinite time period. This may be due to 1) the more detailed explanation about the circumstance under which such a payment would be made, 2) the practice obtained with the YES/NO options with Question 32, and/or 3) the more realistic scenario that an overall ongoing change in the subject's condition might occur that would cause an increase in angina each month. With Question 33 there were three more infinite responses, but fewer problem responses of other types. These were" discussed and evaluated in a previous section.

Table 4.2-4. Summary of responses to the three open-ended willingness-to-pay questions (Questions 30a, 30b and 33)

	WTP 1 Episode	WTP 2 Episodes*	WTP 4 or 8 Episodes/Month*
Total Subjects Asked Question 32	49	35	50
Zero Response	20	8	7
Non-zero, Non-infinite Response	17	16	35
Infinite Response	4	lb	7
Response of $10,000 or More	2	2	0
Don't Know, But Something > 0	4	3	0
Don't Know	2	2	0
Refusal	2	2	1

*12 of the 14 not asked had given $0 to WTP for one episode, the other two were "don't know" responses to WTP for one episode. '

**Numbers in this column reflect adjustments made in 3 responses discussed in text: two "don't know, but something > O" responses were changed to dollar amounts based on their responses to Question 32, and one refusal was changed to zero based on the verbal explanation given.

Of particular interest with respect to the WTP responses concerning one episode is that more than half of the subjects who gave a dollar value said zero dollars. The explanation of this response by all but one of the 20 subjects was that it would not be worth anything to them to prevent just one episode. The one subject said he could not afford to pay anything. Several added further comments that supported the explanation that one angina episode more or less really didn't matter that much. What mattered they said would be an overall change in their condition. Therefore, these 20 zeros were interpreted as true zero bids for preventing a single angina episode.

The means of the dollar responses concerning one and two episodes are as follows (excluding the two very high responses, but including all zero responses):

WTP for One Episode	WTP for Two Episodes
$64 (N-35)	$165 (N-22)

These means are not directly comparable because twelve subjects who said zero to one episode were not asked about two episodes. This was a misinterpretation of the instructions to the interviewers to skip the two-episode question if the subject refused to answer the question concerning one episode. A zero response should not have been interpreted as a refusal. If these twelve zeros are removed from the first mean, as well as a $20 response from a subject who then said he didn't know for two episodes, the two means are more comparable:

WTP for One Episode	WTP for Two Episodes
$100 (N-22)	$165 (N-22)

Of these 22 subjects, two gave infinite responses to Question 33. Due to the small sample size and the apparent lack of difference in responses for. four or eight episodes (see Section 4.2.5), we have combined these responses for this comparison. The means for the remaining 20 subjects for all three WTP questions are:

WTP for One Episode	WTP for Two Episodes	WTP/Month for Four/Eight Episodes/Month
$61 (N=20)	$82 (N=20)	$200 (N=20)

Comparing just the responses for one episode to the four or eight episodes allows 10 zero responses for one episode to be included, and the sample increases to thirty:

UTP for One Episode	WTP/Month for Four/Eight Episodes/Month
$41 (N-30)	$145 (N-30)

These means suggest declining marginal utility for avoiding an increasing number of angina episodes and show general consistency in responses to the three difference questions in terms of the order of magnitude of the per-episode value. The comparison of the means, however, masks a few problems that should be noted. One is the significant number of zeros (higher variance) given for one and two isolated episodes, keeping the mean responses to these questions low. Another is that several subjects gave fairly high

responses to the question regarding one episode and the% didn't increase the response very much for two. It appears from the recorded comments that many subjects may have been focusing on how much they could afford to pay for a reduction in angina but not focusing on the exact amount of angina being avoided, and therefore responded with an estimate that was more related to their budget constraint than to the amount of angina. This tended to bring the means for one and two episodes closer together, giving the impression of declining marginal utility, and perhaps upwardly biasing responses for one or two episodes.

A look at the responses for each individual across the three questions provides some additional, and inconclusive, information about whether the responses show a declining marginal utility for additional episodes reduced. There were 27 non-infinite dollar responses to Questions 30a and 30b that could be compared with the non-infinite, non-zero responses to Question 33. Of these, 11 said zero for one episode, four showed increasing values per episode, and 12 showed equal or decreasing values per episode for the one- and two-episode questions. Of the 12 sets of responses that were consistent with equal or declining marginal utility for additional episodes reduced, four gave the same amount for preventing one or two episodes, and eight gave double the amount for two than for one. Of these same 12 subjects, six showed equal or declining marginal utility across all three questions.

Overall, the responses do not provide conclusive evidence of declining marginal utility for more episodes prevented. The most that can be said is that a good share of the responses, although by no means all of them, show some logical consistency across the different WTP questions. This question is also addressed in the cross-sectional analysis of the WTP responses reported in Section 4.2.5, where there is again no conclusive evidence of declining marginal utility.

4.2.4 Willingness to Pay to Prevent Degradation of Health Status: Analysis of the Close-Ended WTP Responses

In Question 32, subjects were asked if they would pay a given amount per month to prevent an increase of either four or eight angina episodes per month. If they responded "yes," then they were asked if they would pay a specified higher amount, and if they responded "yes" again they were asked if they would pay a third specified higher amount. Question 32 was worded as follows: "Suppose your heart condition were to become worse so that with your current medical treatment and lifestyle your angina episodes would occur more often. Suppose also that a new medical treatment were available that could prevent the additional angina without causing undesirable side effects or requiring lifestyle changes. If the treatment would prevent _____ additional angina episodes per month and you had to pay the entire cost yourself, would you take the treatment if it cost $_____ each month? (Yes/No) Would you take the treatment if it cost $_____ each month? (Yes/No) Would you take the treatment if it cost $_____ each month?"

Payment amount combinations were randomly assigned, and these combinations were previously described in Table 3.3-1.

Overview of Responses

Two subjects refused to answer the close-ended WTP questions. One of these subjects refused to answer all income and financial questions. Another subject said that he wasn't able to decide whether he would be willing to pay the amount asked. Six subjects said they would not pay the first amount

asked. All of these subjects aLso said they would not pay anything to prevent an increase in angina in response to Question 33. Three of these subjects said that they could not afford to pay anything, one said it would not be worth anything to avoid that amount of angina, and two said that what mattered was their overall heart condition, not a few more angina episodes.

Question 32, the close-ended WTP question, combined three questions. to bound the amount a subject was willing to pay to prevent additional angina. With two refusals and three questions for each subject, a total of 144 responses was obtained. When a subject said “no” to one amount, the interviewer went on to Question 33, and the response for any subsequent higher amounts was coded as “no.” About two-thirds of the responses were “yes.” The responses are summarized in Table 4.2-5 and are separated according “to the question sequence. As expected, the percentage of “yes” responses declined as the amount increased. For all amounts under $200, more than half of the responses were “yes.” At $200, the split was 50/50, and for all amounts above $200, one-half or more of the responses were “no.”

Analysis of the Responses

Analysis of the close-ended responses was based on the following utility model. This section follows Hanemann (1984),

$$U - U(A,Y,S) \qquad (4\text{-}1)$$

Where:
- U = an individual’s utility
- A = angina episodes per month
- Y = income (representing all consumption)
- S = socioeconomic characteristics of the individual

Table 4.2-5. Summary of responses to the close-ended willingness-to-pay question (Question 32)

Close-Ended WTP Question Responses

Dollar Amount	Total No. Subjects Asked*	Total Response Yes	Total Response No	Question Sequence: First Yes	First No	Second Yes	Second No	Third Yes	Third No
$5	4	4 (100%)	0 (0%)	4 (100%)	0 (o%)	--		--	
$10	7	6 (86%)	1 (14%)	6 (86%)	1 (14%)	--		--	
$25	18	16 (89%)	2 (11%)	13 (93%)	1 (7%)	3 (75%)	1 (25%)	--	
$50	24	20 (83%)	4 (17%)	7 (78%)	2 (22%)	10 (91%)	1 (9%)	3 (75%)	1 (25%)
$100	29	22 (76%)	7 (24%)	12 (86%)	2 (14%)	8 (73%)	3 (27%)	2 (50%)	2 (50%)
$200	20	10 (50%)	10 (50%)	--		5 (42%)	7 (58%)	5 (63%)	3 (38%)
$300	10	2 (20%)	8 (80%)	--		--		2 (20%)	8 (80%)
$400	12	5 (42%)	7 (58%)	--		--		5 (42%)	7 (58%)
$500	10	5 (50%)	5 (50%)	--		5 (50%)	5 (50%)	--	
$1000	10	3 (30%)	7 (70%)	--		--		3 (30%)	7 (70%)
Total	144	93	51	42	6	31	17	20	28

*Each subject was asked three different dollar amounts. Two subjects refused to answer these WTP questions. Therefore, a total of 144 responses obtained from 48 subjects.

In Question 32, potential changes in A and in Y were hypothesized. The subject's initial utility is

$$u^* = U\ (A_0, T, S) \tag{4-2}$$

Where:
A_0 = the initial level of angina.

Question 32 posed a choice between making a specified payment, X, or having angina frequency increase to A_1, where Al is either A. + 4 or A_0 + 8. Thus, the subject chose between:

$$U. - U(A_0,\ Y\text{-}x,\ s) \tag{4-3}$$

and

$$U_1 - U(A_1,\ Y,\ S). \tag{4-4}$$

Because some components of these utilities are unobservable to the Investigator, they can be treated as stochastic, so that U. and U_1 are random variables with means of $v(A_0, Y\text{-}X, S)$ and $v(A_1, Y, S)$, and distributed according to some probability distribution. U. and U_1 can thus be written as:

$$U_0 - v(A_0,\ Y\text{-}X,\ S) + e_0. \tag{4-5}$$

$$U_1 - v(A_1,\ Y,\ S) + e_1. \tag{4-6}$$

The probability that the subject will be willing to make payment X rather than have angina increase to A_1 is given by the probability that U_0 is greater than or equal to U_1:

$$P_0 - Pr \{ v(A\sim, Y-X, S) + e_0 \geq v(A_1, Y, S) + cl). \quad (4\text{-}7)$$

If we define $E = e_1 - e_0$ and let FE (.) be the cumulative density function of E, then the probability of being willing to pay amount X may be written as:

$$P_0 = F_E (\Delta v), \quad (4\text{-}8)$$

where

$$Av - v(A_0, Y-X, S) - v(A_1, Y, S).$$

In the probit model FE (.) is the standard normal cumulative density function. In the logit model it is

$$P. - FE (\Delta v) - 1/(1 + \exp(-\Delta v)). \quad (4\text{-}9)$$

Hanemann concludes that the argument of FE must take the form of a utility difference to be consistent with the economic hypothesis of utility maximization. He suggests two examples: a linear utility function and a log-linear utility function. Using a linear function, the utility difference is given by:

$$\Delta v = (\alpha + b_1 A_0 + b_2 (Y-X) + b_3 S) - (a' + b_1 A_1 + b_2 Y + b_3 S) \quad (4\text{-}11)$$

$$= a^* + b_1 \Delta A - b_2 X \quad (4\text{-}12)$$

where:

$a^* = a - a'$, and

$\Delta A = A_0 - A1$ (taking a value of -4 or -8).

It would be expected that b_1 is less than or equal to zero because the probability of agreeing to pay X would probably increase when ΔA goes from -4 to -8. It would be expected that b_2 is greater than or equal to zero because as -X decreases (X becomes larger) the probability of agreeing to pay X probably decreases.

The estimation results of the logit form of equation 4-12 are shown in Table 4.2-6. The coefficient b_2 for the X variable, the amount the subject was asked to pay, is statistically significant and has the expected sign. The coefficient b_1 on the change in angina hypothesized does not have the expected sign and is not statistically significant. This is consistent with the finding in the analysis of the open-ended responses that there was not a significant difference in asking about an additional four or eight more episodes.

In order to show the implications of the estimated coefficients, X' is defined as the amount at which Av is zero. This is the amount where the probability of saying "yes" is 0.5, which can be interpreted as a point of indifference between making the payment or having the change in angina. Evaluated at the sample mean of NCHANG (-5.84 angina episodes per month), X'

Table 4.2-6. Logit analysis of responses to the close-ended willingness-to-pay question (Question 32)

A. $\Delta v = a + b_1 (NCHANG) + b_2 (NPAY)$

$X^1 - a/b_2 + (b_1/b_2) (NCHANG)$

Full Sample (N = 144)

Variable	Estimated Coefficient	Standard Error	Prob
Intercept (a)	2.190	.646	.0007
NCHANG	.1430	.095	.1323
NPAY	.0033	.00085	.0001

X^1 -$411 (at NCHANG - -5.84)

B. $Av . a + b_1 (NPAY)$

$X^1 - a/b_1$

Full Sample (N - 144)

Variable	Estimated Coefficient	Standard Error	Prob
Intercept (a)	1.324	.259	.0001
NPAY	.0032	.00084	.0001

X^1 - $414

c. Subsample with Non-Infinite Responses to Question 33 (N - 123)

Variable	Estimated Coefficient	Standard Error	Prob
Intercept	1.951	.703	.0055
NCHANG	.1306	.101	.1952
NPAY	.0037	.001	.0002

X^1 - $321 (at NCHANG- -5.84)

Note: NCHANG = $A_0 - A_1$
NPAY = -X

is $411. This is about twice the mean of the non-infinite responses to Question 33. It would be expected that this value would be higher since those who said they would pay anything are included. To test the impact of the insignificant b_1 coefficient on this estimate of X', the equation was estimated assuming $b_1 = 0$. The X′ value was essentially equivalent at $414.

To determine the extent to which these X′ values may be influenced by the subjects who said they would pay anything and by the subjects who said they would pay nothing, the logit estimation was repeated for the subjects who gave non-zero and non-infinite responses to Question 33. The results are reported in Part C of Table 4.2-6. The coefficients are quite similar to those estimated for the whole sample, but they do result in a considerably lower X′ value of $321.

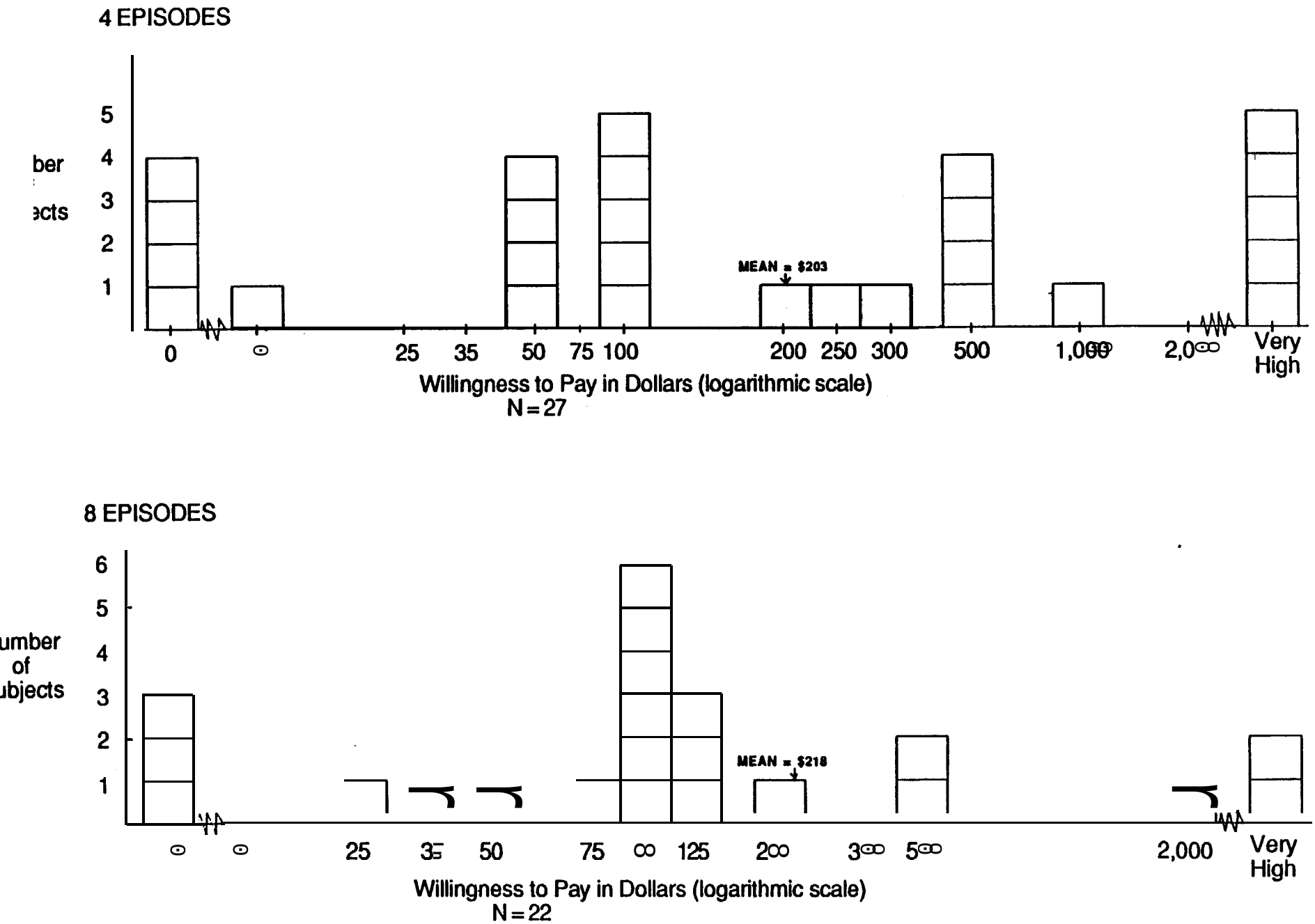
4.2.5 Willingness to Pay to Prevent Degradation of Health Status: Evaluation of Open-Ended WTP Question

In an attempt to obtain a dollar estimate of the total value (utility) angina patients place on preventing a deterioration in health status, we asked an open-ended question immediately after Question 32.

> (Question 33): "What is the most that you would pay for this treatment if it would prevent (four or eight) additional episodes per month?"

Responses to this question are graphed in Figure 4.2-1. Half the subjects were asked the amount they were willing to pay to avoid four additional episodes this month. The other group was asked about eight episodes. Two

Figure 4.2 - 1 Willingness-to-pay in dollars to prevent an additional four or eight episodes of angina



major patterns of response were observed. First, both groups were willing to pay similar dollar amounts to avoid angina. The average WTP for avoiding eight additional episodes ($218) is only $15 more than the average WTP to avoid four additional episodes ($203). These means include all non-infinite responses. Second, a sizable number of subjects (6 of 50 - 12%) said they would pay nothing to avoid the increased angina while another group (7 of 50 = 14%) said they'd give everything they had to avoid Additional angina episodes.

In the next sections the responses of zero and of very high amounts are evaluated to determine whether they should be accepted as true responses or treated as protests. The responses shown in Figure 4.2-1 reflect a few adjustments made on the basis of this evaluation.

Responses of Zero

Six of the 50 subjects gave zero as the maximum amount they would be willing to pay to prevent the increase in angina. Subjects who gave zero were asked a follow-up question to help determine whether their responses indicated that they really would pay nothing to prevent such an increase or whether they gave this answer because they objected to or did not believe the premises of the question. After considering the explanations given by these subjects, all "six zeros were retained as valid responses. In addition, one subject's response was changed from a refusal to a zero because his explanation was similar to that given by other subjects who said zero. This subject had said no to the specific dollar amounts in Question 32.

Two of these subjects said that it would not be worth anything to prevent that much angina, three subjects said that they could not afford to pay anything, and one subject gave both explanations. Subject 16 said that it

didn't matter unless the heart was in good condition, that more or less angina didn't matter that much. One of the other subjects gave a similar explanation saying, "I would mortgage my house and pay $100,000 to be rid of all my angina, but I would not pay to avoid eight episodes." This subject currently had angina about twice a day. Five of these seven subjects reported having angina once a day or more, and apparently several of them felt that an increase of four or eight episodes a month would not be worth paying to prevent, although a significant improvement in their overall condition would be worth a great deal.

All but one of the subjects who gave a zero response to Question 33 had also said no to the amounts suggested in Question 32. One subject had, however, said yes to $100 (the first amount asked for that subject in Question 32) and no to the second higher amount. When asked Question 33 the subject said zero and explained that he really couldn't afford even the $100 he had previously said yes to. This suggests the possibility" that in a close-ended question some subjects will go along with a higher amount than they would actually be willing to pay. Some similarly inconsistent responses are discussed below. This is something that should continue to be checked in future efforts of this type.

Refusals

Four subjects refused to give a dollar response to Question 33. After evaluating the comments and other answers given by each of these subjects, one of these responses was retained as a refusal and the other three were recoded to some dollar amount. As discussed in the previous section, one refusal was recoded to zero because the explanation given by the subject indicated that

the change in angina posed by the question was not significant to him relative to his overall condition.

Two of the remaining three subjects said that they would be willing to pay something, but refused to give a dollar amount. Their responses to the previous Question 32 were used to estimate a maximum amount that they would be willing to pay. One subject had said yes to $25, $100 and $300, but when asked Question 33 this subject had said the amount he would be willing to pay would be less than $300. His response to Question 33 was therefore recoded from a refusal to $100. The second subject had said yes to $25 and $100, and no to $300. This subject said he would be willing to pay something in response to Question 33, so $100 was entered as a response for this subject.

Very High Responses

Seven subjects said that they would pay “anything” to prevent the increase in angina. Several of these subjects recognized by their responses that there would be a limit to the amount of money they could actually pay, but many of them explicitly said that they would sell or mortgage their houses. All these subjects had said yes to every dollar amount asked in Question 32. They emphasized in their explanations that they would place a very high value on preventing an increase in angina. In contrast to the subjects who said zero for Question 33, only one of these seven subjects currently had one or more angina episodes a day. Thus, an increase of four or eight episodes represents a very significant worsening the angina condition for most of these subjects.

All of the very high responses appeared to be sincere indications of a willingness to pay any amount possible to prevent additional angina,

reflecting that such an increase would have a very significant impact on these individuals. None of these responses appeared to be a protest against the question, as is sometimes observed with willingness to pay questions.

The highest dollar amount that these subjects were asked in Question 32 could be interpreted as a minimum estimate of the amount each individual would be willing to pay. These amounts were as follows:

Highest Amount	Number of Subjects
$1000	1
400	1
200	3
50	2

Consistency of Close-Ended and Open-Ended Responses

A comparison was made between responses to Question 33 and the highest amount the subject said he would pay in response to Question 32. Five inconsistencies were observed in which subjects gave a lower amount for Question 33 than the highest amount they had said “yes” to in Question 32. The amounts involved in each case were as follows:

Subject	Amount Agreed to in Question 32	Amount Given in Question 33
7	$500	$100
22	$1000	$200
24	$1000	$500
109	$100	$0
106	$300	$100

Four of these subjects offered the explanation that they really could not afford the higher amount. The other said something to the effect that he

would pay the higher amount if he really had to and the treatment worked. It appeared there might be a tendency for some subjects to go along with a higher amount when the question was asked in the form of a yes/no format. In the subsequent analysis of the open-ended responses, the lower amount given in Question 33 was used. This appears to be a more accurate estimate of the maximum WTP for these subjects.

High Responses Relative to Income

The responses to Question 33 were evaluated relative to the reported household income to determine whether any individuals had given unrealistically high responses relative to their apparent ability to pay. It should be noted that current income is only one indication of the ability to pay as it does not take into account accumulated wealth (such as homes) that individuals may have.

The willingness to pay as a percent of monthly household income was calculated yielding an average of 16 percent. This percentage figure was distributed as follows across the 40 subjects who provided a finite dollar response to the WTP question and answered the income questions.

WTP as Percent of Monthly Income	Number of Subjects
0- 9%	23
10-19	9
20-29	3
30-39	1
40-49	1
50-59	0
60-69	0
70-79	0
80-89	1
90-99	0
100 or more	2

Three responses stand out as being at the high and of the distribution. The information available about each of these subjects was evaluated to determine whether these high responses might be reasonable for these individuals. This information is reported in Table 4.2-7. In light of the apparent sincerity of the very high responses discussed in the previous subsection, it is possible that these high values relative to income are of a similar nature. The information about the three subjects does not contradict this interpretation and the responses were kept as probably valid.

Average WTP After Adjustments

Three different WTP estimates were. defined based on responses to Questions 33 and 32. Q33PAYM was defined as the response given to Question 33, with Subject 16 recoded from refusal to $0 and Subject 2 and Subject 106 recoded from-refusals to $100. The remaining refusal and the very high responses were treated as missing values. Q33ADJ1 was defined as equivalent to Q33PAYM, except the highest value the subject accepted in Question 32 was used if the subject gave a very high response to Question 33. Q33ADJ2 was equivalent to Q33PAYM, except the monthly income was included for subjects who gave very high responses. Q33ADJ1 therefore incorporates the very high responses in a conservative way, and Q33ADJ2 gives an upper bound to the extent that payments are limited by current income.

The means and standard errors of the means for each of the measures are reported in Table 4.2-8. The means for Q33PAYM and Q33ADJ1 are quite similar. The mean for Q33ADJ2 is about twice as large as the other two. When separated for four or eight angina episodes, the means are not statistically

TABLE 4.2-7. Evaluat ion of High WTP Responses Relative to Hi story of Heart O isease and Income

Subiect	mast ion 33 Response	Monthly Household Income (range)	Bypass Surgery	Heart Attacks	Current Angina Frequency	Current Angina Severitv	Response to Question 32	Annual Workloss SWKLOSS	Annual Defensive Expendi tures (OEFCOST)	Additional Commennts
#24	$ 500 recoded to $1000	$ 625 **(417-833)**	**yes**	**2**	**Z/month**	**3**	**$ 100 yes** **500 yes** 1000 yes	s o	s 750	**Would pay $1000 if had to and if it really worked"**
#89	$ 250	$ 208 (0-417)	**no**	1	**3+/day**	**5**	**$ 50 yes** 100 **yes** **200 yes**	$65000	% 0	
#94	$2000	$1875 **(1667-2083)**	**yes**	**2**	**4/month**	4	$ 100 **yes** 200 **yes** 400 **yes**	**$** 9087	$12780	**"You pay as much you can afford"**
Sample Average		**0**	.46	1.5	**15/month**	**3.**		$ **9577**	**$ 904**	

Table 4.2-8. Mean responses to the open-ended WTP Question 33. Responses a-re adjusted for consistency with WTP dollar amounts elicited from the close-ended Question 32. Q33ADJ1 is equivalent to Q33PAYM except that the highest value accepted in Question 32 was used for subjects who gave very high responses to Question 33. Q33ADJ2 is equivalent to Q33PAYM except that monthly income was used for subjects who gave very high responses

	922X2!	Q33ADJ1	Q33ADJ2
All subjects	$210	$223	$499
	(SE_ = 54)	(SE_ = 49)	(SE_ = 121)
	x (N - 42)	x (N - 49)	x (N = 49)
4 episodes	$203	$204	$590
	(SE_ = 54)	SE_ = 45)	(SE_ - .17.7)
	x (N - 22)	x (N = 27)	x (N = 27)
8 episodes	$218	$246	$387
	(SE_- 99)	SE_ - 97)	(SE_ = 163)
	x (N - 20)	x (N = 22)	x (N = 22)
WTP/episode	$40	$42	$103
	(SE_- 9)	(SE_ = 8)	(SE_ = 27)
	x (N - 42)	x (N = 49)	x (N - 49)

different. This suggests that four and eight episodes per month were not viewed as significantly different by the subjects, or at least that no difference shows up cross-sectionally for a small sample of subjects with current angina frequency varying from zero episodes per month to 90 or more episodes per month. This is discussed below and explored further in the analysis of the willingness to pay responses.

The average WTP per episode was $40 for Q33PAYM, $42 for Q33ADJ1, and $103 for Q33ADJ2. Although the latter is about two and one-half times the other two values, it suggests that if the subjects who gave infinite responses are taken into account, a value per episode is likely to be between $50 and $100.

Another summary statistic of interest is that the median and the mode for each of these measures is $100. This is true for four episodes and eight episodes. The median and the mode of the anchoring values asked in Question 32 are also $100, indicating that these values may have influenced the responses to Question 33. This observation is explored further in the analysis of the WTP responses (Section 4.2.5, subheading “Suney Instrument Influences”).

Lack of Differences Between Responses Concerning Four and Eight Episodes of Angina

The similar aggregate patterns of responses to the four and eight episode WTP questions might be interpreted in at least four ways, assuming the subjects in the two groups are similar on other characteristics. It must be emphasized that these are hypotheses for future research, not conclusions of the study.

First, relative to the wide range of angina severity/frequency experienced by the subjects, four and eight episodes per month may not be perceived as a very different health level. For example, for subjects currently having angina twice a day, four or eight episodes a month may not seem like very much, while subjects having angina once a month may see both four and eight added episodes as a significant increase. With the small sample size, it may be difficult to detect small real differences in WTP.

Second, the responses may show rapidly decreasing marginal value (utility) for avoiding additional episodes. This possibility was explored in Section 4.2.3, in which responses for willingness to pay for one or two isolated angina episodes are reported. The data are inconclusive regarding the presence of declining marginal utility for additional episodes reduced.

Third, the responses for willingness to pay for preventing additional episodes may have been at the maximum possible level regardless of the amount of angina reduced. Responses and comments suggest that some subjects were focusing more on what they could afford to pay than on the amount of angina being hypothesized. In Questions 30a and 30b, each subject was asked his willingness to pay for avoiding both one and two episodes. From a few subjects' comments, it was seen that income constrained some answers. For example, when asked about paying to avoid one typical angina episode, Subject 18 answered $100 and added "I just don't have the money. If I made a salary then I'd pay more. I'd have to consider what would happen to my family if I paid more." For two episodes the subject also answered $100, stating, "Just couldn't pay any more." Subject 22 answered $500 for both one and two episodes and stated "$500 is the most I can give for 1, 2, 5 or whatever." Similarly, some subjects would have paid everything they had to avoid 1, 2 or more additional episodes.

These subjects may have given a response indicating how bad additional angina would be, but the response was not specific to a certain number of episodes. This is likely to happen if people have difficulty separating angina symptoms from IHD as a whole. If this was the case, using a variable such as "willingness to pay to avoid x additional angina episodes" in a model for evaluating CO may be inappropriate.[2]

Further, it may be the case that decision-based valuation questions are inappropriate for exploring the impacts of angina on subjects because they oversimplify the issue. When asked to give a dollar amount to avoid a specific number of episodes, a subject may respond to the "demand" for an answer even though the question is not consistent with how he views his symptoms. Much of the subject's behavior results from many small decisions or changes that become habits. Long-term angina sufferers may be able to describe their habits (such as resting whenever short of breath), but not be able to describe the tradeoffs they made in acquiring those habits. " Hypothetical decision questions, such as asking for a decision on an amount to pay to avoid excess angina, are framed with a context and a response mode which may not match the patient's perspective. For example, some subjects. who no longer work indicated that this wasn't bothersome at all anymore, though it did bother them in the past. See Keller and Lambert (1986) for a discussion of the problem of measuring habitual behaviors via decision questions. In

[2]In fact, clinical laboratory research has shown that CO aggravates angina, but it is still unclear whether it increases the risk of myocardial infarction. If it is found that CO doesn't increase risk of death, then it would be important to explain to subjects the health effects of increased angina and to separate risk of death from other effects. We probed the subjects' opinions on the relationship between angina and heart health in Question 37; 60 percent (N = 50) of the subjects said their heart is probably not harmed when they have an angina episode (indicating the angina is simply their bodies' warning to slow down). Thirty-six percent said their heart may be harmed a small amount; half of these people believe it probably does not heal and half believe it probably does heal.

this questionnaire, it was suspected that subjects could make more sense of hypothetical tradeoffs when the more realistic context was used (in Questions 32 and 33) of an ongoing change in health status rather than one episode (as in Question 30). In general, the responses to the defensive expenditures questions indicate that subjects did make direct tradeoffs that they were aware of.

There are other potential problems with using WTP measures to value angina reduction. It is important to mention these problems, and great care was taken in designing the questionnaire to prompt subjects after certain WTP responses to give their reasons behind the response. First, patients may discount their willingness to pay to avoid angina if they see angina as an early warning to slow down before precipitating a myocardial infarction. Second, patients "pay" to avoid attacks by avoiding exertion, rather than spending money. Finally, reducing the number of angina attacks (without a complete cure) may not reduce the psychological and behavioral effects on the patient, his family and friends (Keller and Lambert, 1986).

Bimodal Distribution of WTP Responses

It may seem paradoxical that some angina patients indicated they would pay zero to avoid added angina attacks while others said they would pay everything they had to avoid the next episode(s). One exploratory analysis using cross tabulations of the WTP responses versus responses to the health, attitude, and demographic questions did not reveal any systematic differences between those responding zero and those responding "everything they own". (An alternative analysis based upon disease and surgery history in Section 4.2.6 is more promising.) The Classification and Regression Tree (CART) software

package by Breiman et al. (1984) for classifying items (i.e., angina patients) into homogeneous categories, based upon multiple characteristics (i.e., responses to survey questions), did not work on this data set due to small sample size and relatively homogeneous responses. As reported in Section 4.2.6, the dollar amount all subjects (not just those giving zero or very high responses) were willing to pay to prevent four or eight episodes was significant and positively related to annual household income, to having had coronary artery bypass surgery, etc.

McClelland et al. (1986) have found a similar pattern of responses for WTP bids for insurance to protect against a $4 or $40 loss in an experimental laboratory setting. They found a bimodal distribution of bids, with one mode at or near $0 and the other mode a high amount, above the expected value of the monetary risk being faced. This pattern occurred when the probability of loss was low (10 percent or 1 percent). Since the probability of death following one angina episode is low, it may be useful in further research to explore whether the behavior observed in these "low probability of loss" laboratory experiments can give us clues to the angina patients' response pattern. McClelland et al. (1986) hypothesized that the bimodal answers resulted from the influence of two cognitive processes: editing, and anchoring and adjustment.

In the angina context, these processes can be used to interpret the zero and everything answers given by some subjects. First, editing refers to a stage prior to decision making when a person simplifies a problem by selectively focusing on only some of the possible outcomes and the perceived chances of those outcomes. The simplified problem is then used as the model for decision making. When facing one or a few additional angina episodes, some subjects may have considered the probability of death from the episode(s)

as being very small and edited the problem by considering this probability virtually zero. Then, paying zero to avoid an added episode makes sense when the probability of death is seen as zero. Some subjects' comments indicated they were focusing on the insignificance of the marginal change in symptoms being hypothesized, especially when they were currently experiencing a great deal of angina.

Second, some people may be anchoring on the possible loss from ischemic heart disease as a whole (severe pain, total incapacitation or even death from a heart attack). They then consider how much they'll pay to avoid this loss (everything they have) and adjust downward since the loss will not occur for sure. Some subjects' comments indicated they were focusing on the significance of their disease in a larger sense and on how they would do "everything" to improve it. However, although the coefficient on the variables "concern about heart attack" was positive in the willingness-to-pay regressions, it-was not very significant. So, some subjects may have focused on the disease as a whole and others may have narrowed the focus to just angina. Even if death from IHD is not considered, other aspects of the disease such as worry to family and friends and ability to hold a job may enter into the decision process.

In the McClelland et al. (1986) laboratory experiments, the fraction of subjects who bid $0 increased when there were repeated trials without experiencing the loss. Similarly, the dollar amount of bids by those stating a positive amount decreased when there were repeated trials without loss. This suggests that angina subjects who have not experienced a myocardial infarction recently might be more likely to bid $0 than others. Unfortunately, due to a small sample size, it was not possible to statistically test this hypothesis. Table 4.2-9 contains a cross-tabulation

Table 4.2 - 9 Number of years since myocardial infarction and willingness-to-pay to avoid four or eight angina episodes

		This Year 1986	Last Year 1985					14 Years Ago (72)	Row Total
		0	1	2	3	4	11	12	14	
No Money	0		1	1	1	1	1	1		6 18.8%
Some Money	1	3	3	9	3	3	1		1	23 71.9%
Infinite Money	2			1	1				1	3 9.4%
Column Total		3 9.4%	4 12.5%	11 34.4%	5 15.6%	4 12.5%	2 6.3%	1 3.1%	2 6.3%	32 100.0%

of the number of years since a myocardial infarction (for the 32 subjects who had them) and response to the willingness to pay question about either four or eight episodes (Question 32). Unfortunately, this does not reveal a suggested pattern. Future surveys should ask the subject how long he has had angina, since behavior and judgment processes may have altered over the course of the disease.

A less plausible reason for the observed zero and infinity answers is that subjects might have been framing the problem in two different ways. Some subjects may have been framing the problem as the amount they were willing to pay to avoid decrements in health status (the original intent of the questions) and others may have framed the questions as the amount of compensation they would demand from an agent who will cause adverse health effects. At least one subject considered different problem frames prior to responding to the willingness to pay question. Subject 43 asked why the study was being done. He said he thought perhaps the government had cut back on the research funds and that they were going to ask for funda. He also wanted to know whether there was some medical treatment developed that would get rid of angina, but that had not been made public. Previous research has demonstrated that people respond differently to the two problem frames, (Gregory, 1986; Knetsch and Sinden, 1984). An interesting question for further research is whether framing a problem as one of "compensation demanded" leads more people to anchor on the potential loss and adjust downward to reflect lack of certainty that it will happen. Framing a problem as willingness to pay may lead more people to edit the risk to zero.

There is another possible explanation for the zero/everything phenomenon. Subjects can be divided into "those who give very low values for willingness to pay to avoid extra angina because they feel that they should bear the

burden of the disease themselves and not bother others with it, and those who give very high values because they feel that they deserve to devote whatever resources are available to easing their burden" (Keller and Lambert, 1986). Ramshaw and Stanley (1984) found a similar pattern. They divided angina patients who had undergone CABG into two groups. People who had scored low on a neuroticism scale and coped well with previous stressful situations generally rated themselves as "well off" one year after their operation. In contrast, those who scored high on neuroticism and had not coped well with stress did not rate themselves as well off as the other group.

Future research on the zero/everything phenomenon will clarify the understanding of the way angina patients value improvements in their symptoms and may suggest alternative research paradigms for eliciting the information needed for making policy decisions about health risks resulting from environmental pollutants. The discussion here is purposefully speculative and is "meant to stimulate further research rather than to imply that this study provides much evidence for testing the different hypotheses.

4.2.6 Analysis of Relationship of Open-Ended WTP Response with Other Responses

Regression analysis was used to identify relationships between responses to Question 33 and potential explanatory factors, including personal characteristics and survey instrument factors. Regression results obtained for Q33PAYM (dollar payment per month to prevent four or eight angina episodes) are reported in Table 4.2-10 (a and b). The variables are defined in Table 4.2-11 and means for the variables are given in Table 4.2-12. The two presented regressions differ in the use of either defensive expenditures

Table 4.2-10a. Regression analysis predicting willingness-to-pay dollar amounts from the open-ended WTP Question 33. Defensive expenditures are represented by DEFANG, the defensive expenditure per angina episode avoided

Regression Analysis

Equation 1

Dep Variable: Q33PAYM

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB > F
MODEL	9	2616023.65	290669.29450	3.544	0.0055
ERROR	26	2132581.91	82022.38096		
C TOTAL	35	4748605.56			

ROOT MSE	286.3955	R-SQUARE	0.5509
DEP MEAN	208.8889	ADJ R-SQ	0.3954
C.V.	137.1042		

Parameter Estimates

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T For Ho: PARAMETER = 0	PROB > |T|
INTERCEP	1	-936.101	345.22521914	-2.712	0.0117
CHANG	1	42.49950139	28.60039065	1.486	0.1493
Q43HINCM	1	1.24954930	0.40493782	3.086	0.0048
MONFREQC	1	5.89451688	3.17960235	1.854	0.0751
SURG	1	246.54566498	118.32953508	2.084	0.0472
SURGANG	1	-12.2347	4.67304211	-2.618	0.0145
DEFANG	1	6.18485953	1.58929489	3.892	0.0006
PAY1	1	3.66830380	1.43707072	2.553	0.0169
COISELF	1	-0.000998279	0.002967415	-0.336	0.7393
Q31GMI	1	31.25966729	19.79188162	1.579	0.1263

Table 4.2-10b. Regression analysis predicting willingness-to-pay dollar amounts from the open-ended WTP Question 33. Defensive expenditures are represented by DEFCOST, the total annual defensive expenditure

Regression Analysis

Equation 2

Dep Variable: Q33PAYM

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB > F
MODEL	9	2617112.80	290790.31082	3.547	0.0054
ERROR	26	2131492.76	81980.49070		
C TOTAL	35	4748605.56			

ROOT MSE	286.3224	R-SQUARE	0.5511
DEP MEAN	208.8889	ADJ R-SQ	0.3958
C.V.	137.0692		

Parameter Estimates

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T For Ho: PARAMETER = O	PROB > |T|
INTERCEP	1	-764.436	334.75028533	-2.284	0.0308
CHANG	1	37.40540586	28.55545084	1.310	0.2017
Q43HINCM	1	1.07454138	0.39248825	2.738	00.0110
MONFREQC	1	4.39890900	3.12352005	1.408	0.1709
SURG	1	218.73022059	118.65061709	1.843	0.0767
SURGANG	1	-11.5897	4.67027184	-2.482	0.0199
DEFCOST	1	0.06746431	0.01732397	3.894	0.0006
PAY1	1	3.62645011	1.43755033	2.523	0.0181
COISELF	1	-0.000802583	0.002970846	-0.270	0.7892
Q31GMI	1	24.22031521	19.43102467	1.246	0.2237

Table 4.2-10c. Regression analysis predicting willingness-to-pay expressed as a percentage of monthly income (PAYINC)

Regression Analysis

Equation 3

Dep Variable: PAYINC

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB > F
MODEL	9	1.22093904	0.13565989	3.144	0.0107
ERROR	26	1.12178613	0.04314562		
C TOTAL	35	2.34272516			

ROOT MSE	0.2077152	R-SQUARE	0.5212
DEP MEAN	0.1421593	ADJ R-SQ	0.3554
C.V.	146.1144		

Parameter Estimates

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T For Ho: PARAMETER = 0	PROB > |T|
INTERCEP	1	-0.400396	0.25038291	-1.599	0.1219
CHANG	1	0.0209298	0.02074312	1.009	0.3223
Q43HINCM	1	0.0002473776	0.0002936909	0.842	0.4073
MONFREQC	1	0.006316575,	0.002306083	2.739	0.0110
SURG	1	0.14229324	0.08582135	1.658	0.1093
SURGANG	1	-0.00898299	0.003389236	-2.650	0.0135
DEFANG	1	0.003218624	0.0011526746	2.792	0.0097
PAYI	1	0.002298914	0.00104227	2.206	0.0364
COISELF	1	.00000358463	.00000215219	1.666	0.1078
Q31 GMI	1	0.007541569	0.01435454	0.525	0.6038

Table 4.2-11. Definitions of Regression Variables

Q33PAYM	Responses to Question 33 with recodes to $0 for Subject 16 and to $100 for Subjects 62 and 106, in dollars per month to prevent an increase of four or eight angina episodes per month.
PAYINC	Q33PAYM/(Q43HINCM/12): Willingness to pay to prevent an increase in angina as a percent of monthly household income.
CHANG	Change in angina posed to subject, either four or eight episodes per month.
Q43HINCM	Annual household income in $100s, midpoint of range selected for Question 43.
MONFREQC	Current frequency of angina in episodes per month, adjusted from the 1-9 scale in Question 6 to number of episodes per month. Subjects who report no angina at present were coded as .01/month.
SURG	If subject has had bypass surgery, SURG = 1. Otherwise, SURG = 0.
SURGANG	SURG*MONFREQC: Current angina frequency for subjects who have had surgery, 0 for subjects who have not had surgery.
DEFANG	Defensive expenditure per angina episode avoided, based on Questions 20c, 20d, ALT-20b, and ALT-20c.
DEFCOST	Total annual defensive expenditures in dollars, based on Questions 20c, 20h, 20i, ALT-20b, and ALT-20g.
PAYI	The first dollar amount the subject was asked in Question 32.
COISELF	Annual income lost to subject in dollars due to angina, based on Questions 21, 21d, 21f, 21g, ALT-21, and ALT-21c, and medical expenses incurred by the subject in the past year.
Q31GMI	Rating given (on 1 to 10 scale) of the concern about increased risk of MI that the subject would feel if angina became more frequent.

Table 4.2-12. Summary of means and variances of varables used in the regression analyses

Variable	N	Mean	Standard Deviation	Minimum Value	Maximum Value	Std Error of Mean
Q33PAYM	42	210.0000	351.2087	0.0000	2000.0000	54.1927
PAYINC	40	0.1637	0.2698	0.0000	1.2000	0.0427
CHANG	50	5.8400	2.0138	4.0000	8.0000	0.2848
Q43HINCM	47	220.2128	152.2154	25.0000	650.0000	22.2029
MONFREQC	50	15.4414	24.8640	0.0100	90.0000	3.5163
SURG	50	0.4600	0.5035	0.0000	1.0000	0.0712
SURGANG	50	6.6406	14.2633	0.0000	60.0000	2.0171
DEFANG	45	13.5157	30.2717	0.0000	140.0000	4.5126
DEFCOST	50	903.5800	2523.4981	0.0000	12780.0000	356.8765
PAY1	50	47.0000	36.1967	5.0000	100.0000	5.1190
COISELF	50	9833.0	18258.0	0.0	65374.0	2582.5
	50	7.120	3.114	1.0	10.0	0.440

per angina episode avoided (DEFANG), or total annual defensive expenditures (DEFCOST) as the independent variables. The adjusted R-squared statistics indicate that about 40 percent of the variation in Q33PAYM is explained by the independent variables in each of these regressions. This is reasonably good for a small sample of cross-sectional information (the best adjusted R-squared obtained by Rowe and Chestnut (1986) in a similar analysis was .25). Some alternative specifications that were rejected in favor of these two regression models are discussed below.

One additional regression is reported in Table 4.2-10C. The dependent variable is PAYINC, the willingness to pay as a percent of monthly income. This dependent variable was defined because several of the subjects said that they would pay as much as they could afford to prevent any additional angina. Therefore, it seemed that their responses might be appropriately characterized in relation to their incomes. The explanatory power of the independent variables is, in general, very similar for the PAYINC regression.

The regression results are discussed below in terms of the effects of the independent variables on the willingness to pay measures.

Change in Angina Episodes (CHANG)

One important result of the regression analyses, with implications for future instrument design, is that the CHANG coefficient is positive, as expected, but is not statistically significant (Table 4.2-10a-c). This is consistent with the finding that the means of Q33PAYM for four and eight episodes are not significantly different, suggesting that subjects did not find four and eight episodes per month sufficiently distinct.

Two alternative measures of change in angina frequency were considered. One possibility considered whether it was the change relative to the current level that was important, but variables defined as 1) percentage change from current angina frequency, and 2) as the ratio of current angina frequency to proposed new level, were also insignificant relative to Q33PAYM. Another possibility considered in the analyses was a constant elasticity of WTP with respect to changes in angina frequency. This would result in a declining value per additional episode prevented, so that a constant total WTP would be observed and WTP would appear to' be unrelated to the number of episodes. If this were the case, Q33PAYM/CHANG could be expected to be negatively related to CHANG. fiis relationship was, however, found to be insignificant.

These results suggest that asking some subjects about four episodes and some about eight episodes per month was not sufficient to determine how WTP could be expected to change as a function of the size of the change in angina. This may be due to four and eight episodes being quite similar relative to the current range in angina frequency among the subjects: O to 90 or more episodes per month. A recommendation for subsequent instrument design is that each subject be asked about more than one size change, and/or that the change in angina posed to the subject be treated as a percentage change from current frequency or tied in some other way to the current level.

Income (Q43HINCM)

Annual household income was found to be positively related to Q33PAYM (P - .005 in Equation 1 and p - .011 in Equation 2). This is a stronger relationship than is found in similar WTP estimates and may reflect the feeling expressed by many of the subjects that they would pay whatever they

could afford to -prevent additional angina episodes. The implied income elasticity (the percent change in WTP for a one percent change in income) at the variable means is 1.3 for Equation 1 and 1.1 for Equation 2.

The results in Table 4.2-1OC indicate that income is not related to PAYINC. This means that subjects with higher household incomes were not giving WTP responses that reflected a higher percentage of income, as might have been expected.

Current Angina Frequency and Disease History

It was expected that heart condition at the time of interview and medical history would influence WTP. Four variables were used to describe heart health. MONFREQC is the average number of angina episodes the subjects reported as currently experiencing each month. Seven of the 50 subjects reported having no angina at present, although they had previously had angina attacks. For these subjects MONFREQC was given a value of .01. It was expected that MONFREQC would be insufficient to fully characterize the subject's experience with heart problems because it does not take into account how ill the subject might have been previously. Therefore, a variable for whether the subject had had bypass surgery (SURG), an interaction term of angina and surgery (SURGANG - MONFREQC * SURG), and the number of heart attacks the person had had (NUMMI) were also used. NUMMI was dropped because the estimated coefficient was insignificant in all specifications.

The estimated coefficient for MONFREQC was positive, as expected, and was statistically significant ($p < .10$) in Equations 1 and 3. It was expected that subjects who had had surgery might be more concerned about preventing an increase in angina. The coefficient for SURG was positive and significant ($p < .10$) in most of the specifications.

The coefficient for SURGANG was neghtive and significant ($p < .05$) in all the specifications. The expected sign for SURGANG was negative because the difference between subjects who had and had not had surgery was expected EO be greatest for those with the lower levels of current angina frequency. Thus, a subject who had surgery and was now experiencing low current angina would be expected to respond to the WTP question more like a person who was currently experiencing more frequent angina. Moreover, they have just paid a significant amount (if not in money then in personal energy) related to having surgery to reduce angina. However, a person who had surgery but now had many angina episodes would have a larger decrease in WTP relative to others, perhaps because of an attitude that the angina could not be made better. An alternative approach might use levels of angina experienced previous to treatment, surgery, or lifestyle change. This information was not obtained, but should be considered in future instrument design.

To show the combined effects of the coefficients for MONFREQC, SURG and SURGANG, derivatives were calculated for Q33PAYM and PAYINC with respect to MONFREQC and SURG for Equations 1 and 3. These are shown in Table 4.2-13. For subjects who had not had bypass surgery, the derivative of Q33PAYM with respect to MONFREQC was 5.9. This means that for subjects who had not had bypass surgery, every additional episode per month in terms of current angina frequency was associated with a $5.90 increase in Q33PAYM. For subjects who had surgery, the derivative was -6.3. That this is negative means a subject who had surgery and low angina would have been willing to pay more to prevent an increase in angina than a subject who had surgery and high angina frequency. This latter group might be more inclined to feel that a change of four or eight episodes was not significant, and that the increase is inevitable.

Table 4.2-13. Derivatives of WTP with respect to MONFREQC and SURG

MONFREQC

Equation 1

$$\frac{\delta Q33PAYM}{\delta MONFREQC} = 5.9 - 12.2 * SURG$$

For SURG - 0: $\frac{\&233PAYM}{\delta MONFREQC} - 5.9$

For SURG - 1: $\frac{\delta Q33PAYM}{\delta MONFREQC} - -6.3$

Equation 3

$$\frac{6PAYINC}{\delta MONFREQC} - .0063 - .0090 * SURG$$

For SURG - 0: $\frac{\delta PAYINC}{\delta MONFREQC} - .0063$

For SURG - 1: $\frac{\delta PAYINC}{\delta MONFREQC} - -.0033$

SURG

Equation 1

$$\frac{\delta Q33PAYM}{\delta SURG} = 246.5 -12.2 * MONFREQC$$

Shifts from positive to negative at **MONFREQC = 20**

Equation 3

$$\frac{\delta PAYINC}{-} = .14 - .0090 * MONFREQC$$

Shifts from positive to negative at MONFREQC - 16

The derivatives of the WTP measures with respect to SURG are positive over the lower range of angina frequencies, indicating that for these subjects WTP was higher if the individual had had bypass surgery. At high frequencies of angina (20 per month in Equation 1 and 16 per month in Equation 3), this derivative becomes negative, indicating that WTP was lower for subjects who had had bypass surgery.

These findings generally confirm the expectation that subjects who have more severe heart conditions are willing to pay more to prevent that condition from becoming worse, but they also illustrate the complexity involved in characterizing an individual's condition. The findings are also consistent with the comments offered by some subjects that a change in angina of four or eight episodes per month would not have been that important to them, and that it was their overall condition that concerned them. It appears this kind of response is more likely to be obtained from subjects who have had surgery and still experience a high frequency of angina; in other words, subjects who, by these measures have the most severe conditions.

Defensive Expenditures (DEFANG AND DEFCOST)

Estimates of defensive expenditures incurred by each subject were positively and significantly ($p < .01$) related to WTP in each of the specifications. " In Equation 1, the coefficient for DEFANG was about 6, indicating that for every dollar increase in the amount the subject was currently spending to prevent an additional angina episode (DEFANG), WTP to prevent four or eight additional episodes increased by $6.00. Since the average number (across all subjects) of additional episodes hypothesized was 5.8, the DEFANG coefficient implies nearly a one-to-one relationship between

what the sublets was currently spending to prevent an angina episode and what he said he would be willing to spend to prevent an additional episode. This is strong support for the hypothesis that the subjects were giving responses to Question 33 that were consistent with their circumstances.

The coefficient for DEFCOST was also positive and significant. DEFCOST was the total annual defensive expenditure incurred regardless of the number of episodes reduced. This coefficient indicated that subjects who were spending more were willing to pay more to prevent additional episodes. One possible factor that may contribute to these findings is that subjects who said they were incurring expenses to prevent angina may have been more willing to consider the idea presented in Question 33 (that a payment might be related to angina frequency) and might therefore have given higher dollar responses.

Income Lost and Out-of-Pocket. Medical Expenses Due to Angina

The coefficient for COISELF was not significant in the Q33PAYM equations, but was positive and marginally significant (p - .11) in the PAYINC equations." This suggests that subjects with more lost income and out-of-pocket medical expenses due to angina were willing to pay a higher percentage of their current monthly incomes to prevent an increase in angina.

Survey Instrument Influences

It was hypothesized that the dollar amounts the subjects were asked in the close-ended willingness-to-pay Question 32 might influence their responses to the open-ended Question 33. This was supported by the finding of a significant ($p < .05$) coefficient for the first dollar amount asked of the

subject (PAY1) in every specification. The size of the coefficient in the Q33PAYM equations was about 4, indicating that for every dollar increase in the first amount asked in Question 32, the response to Question 33 increased by about $4. This is evidence of a strong starting point anchoring bias.

Other specifications of the effects of Question 32 were also tested. The third amount asked and the difference between the first and second amounts were also positively related to responses to Question 33, but the statistical significance was not quite as strong as for PAY1. These measures were all correlated to some extent and may therefore be reflected in the PAYI. coefficient. In other words, a higher value for PAYl means that there was often a larger increment between the first and second amounts in addition to the first amount being higher.

The order of the questions concerning one angina episode (Question 30, which was moved to follow Question 33 part way through the interviews) was not found to be significantly related to the non-infinite responses to Question 33.

The finding of a strong starting point bias from Question 32 poses a problem for future instrument design. Preliminary interviews suggested that the subjects would have a hard time answering an open-ended WTP question due to difficulty with the concept of trading dollars for health and to a lack of experience with deciding how much they would be willing to pay. Therefore, Question 32 was added to obtain some information about WTP in case Question 33 received too many refusals and to get the subjects thinking about how much it would be worth to prevent additional angina. This seemed to be helpful in preparing them to answer Question 33, but it apparently also influenced their answers. Future efforts may need to continue to use some preliminary questions before subjects will be ready to answer an open-ended WTP question,

but potential effects of these preliminary questions should be thoroughly considered in the analysis. For example, yea saying to the first dollar amount in closed-ended referendum bidding questions may occur, resulting in a bias similar to the starting bid bias in an interactive bidding approach. Some evidence of this behavior was found in this application, but the sample sizes were too small to address the concern.

Concern About Heart Attacks

The rating given by the subject regarding concern about heart attacks or bypass surgery if angina were to increase, Q31GMI, also was included in the regression. The estimated coefficient was consistently positive, but not statistically significant.

This issue should be further explored in future research efforts. It was apparent from responses to several questions that for many of the subjects concern about temporary or permanent heart damage was associated with angina symptoms. A variable such as Q31GMI might be statistically significant in a larger sample. In response to Question 37, 18 out of the 50 subjects said they thought some heart damage was associated with angina pain. When subjects were asked about help hired to reduce risks of angina, 19 out of 20 subjects responding to this question said they thought their risk of heart attack would be higher if they did this work themselves. This all suggests that for some subjects, concern about heart attacks may be reflected in responses to WTP for changes in angina frequency. To the extent that perceived changes in welfare are to be considered, this inclusion may be valid whether or not it is medically correct.

4.3 Averting Behaviors

In Questions 20 and ALT-20, subjects were asked about non-medical expenditures they had made in the past year to reduce or prevent potential angina symptoms. The most common expenditures were for hiring help with yard work and car maintenance that would otherwise have been done by the subjects themselves. Goods purchased to prevent additional angina included lawn mowers, household appliances and new automobiles (to ensure reliable transportation and reduce maintenance work).

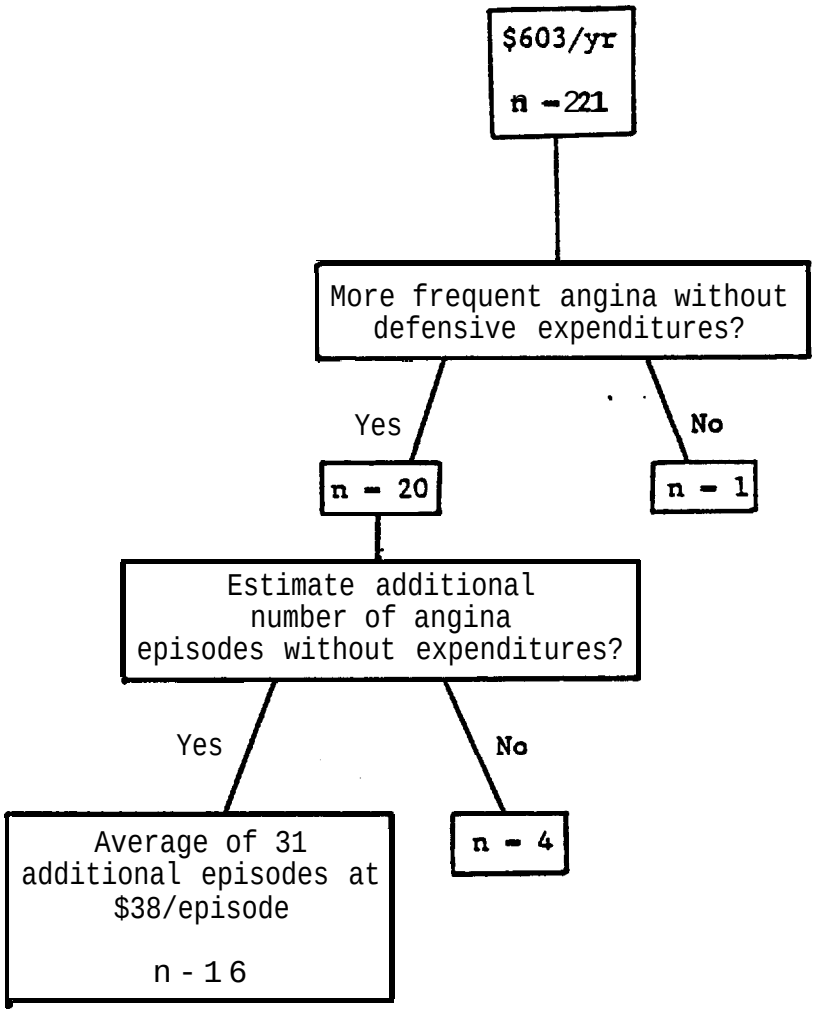
The 21 subjects with these expenditures were asked to estimate their annual costs for the help they most often hired. The results are summarized in Figure 4.3-1. Including answers to Questions 20c and ALT-20b only, the average annual expense for this item was $603 (Figure 4.3-l). Other defensive expenditures in Questions 20h and 20i were not included. Twenty of the subjects with these expenses said that they believed they would have experienced more frequent angina if they had not incurred this expense, and sixteen of them were able to give an estimate of the additional episodes they might have had. The average estimate was 31 additional episodes in a year. With this estimate it was possible to calculate an estimate of the expenditure per angina episode avoided for these 16 subjects. The average expenditure per angina episode was $38, with a minimum of $3.50 and a maximum of $140.

It is interesting to note that the average willingness to pay given in response to Question 33 for this group was $28 per angina episode avoided (with two of the 16 subjects giving very high values). That these subjects were actually spending a similar amount per episode avoided supports the credibility of the WTP estimates. This comparison is not exact, however, because these two dollar measures do not necessarily reflect exactly the same

Figure 4.3-1

Average Averting Expenditures

(Single Expense Listings)



Note: Including multiple expense listings for the group of 21, average averting expenditures were $2,151 per year (n = 21).

thing. Even though we asked subjects to list services that they would not purchase if they did not have angina, there may be some joint benefit ***to*** the subject from the purchase (for example, angina is avoided and time is freed from mowing the lawn). Also, the subject's ability to reduce risks of angina is probably not reflected by a smooth or continuous production function. The individual may be forced to choose between purchasing too little or too much relative to the actual utility optimizing amount.

Fourteen of the 21 subjects with some expenses gave more than one example. With information provided by the subjects, and estimates of typical costs of services, an estimate of total annual defensive expenditures for each of the fourteen subjects was developed. Answers to Questions 20c, 20h, 20i, ALT-20b and ALT-20g were used along with the following estimates of costs:

Activity Category	Cost per" Event
meal preparation	**$15**
indoor cleaning	**30**
outdoor cleaning	**25**
indoor repairs	**75**
outdoor repairs	**150**
appliance repair	**40**
car maintenance	**40**
meals at restaurants	**15**

For the 21 subjects with some defensive expenditures, the average annual total expense was estimated to be $2,151, ranging from $84 to $12,780.

Given the existence of significant defensive activity on the part of the angina subjects, it is of interest to explore the decision to mitigate or avert the potential adverse health effects. Therefore, the following will identify characteristics that determine whether an individual will undertake defensive behavior, examine the factors that may explain the actual level of defensive spending, and finally examine the relationship between defensive activity and exposure to CO.

Factors Influencing Defensive Spending

Defensive behavior was indicated by a positive response to survey questions about hiring help for yard work, home, or auto maintenance, or for purchasing special equipment. These purchases would reduce physical exertion which has been linked to the aggravation of angina. It was hypothesized that the decision to undertake a defensive expenditure would depend on several factors, including ability to pay, attitude towards risk, previous health habits and awareness, severity of angina, age, and household size. The latter could involve two opposite effects. First, it might be expected that in bigger households, there would be less need to hire outside help since household members can share the responsibilities for yard and repair work. Conversely, in larger households there may be more direct and implicit pressure for the individual with a heart condition to take better care of himself. Also, if the household includes younger children, there may be more demands on the subject.

This hypothesis was explored using both a linear probability model in ordinary least squares regression and a logistic model, A binary variable was created which indicated whether a subject identified himself as having had defensive expenses. With the linear probability model, a forward stepwise procedure was used to select from among a large number of candidate explanatory variables. Variables selected at the 0.500 significance level of entry were used to specify a logistic model. Since the logistic model generated results similar to the linear probability model, only the linear probability model is described in full in this text. The results of the least squares regression are displayed in Table 4.3-1.

Table 4.3-1. Regression analysis predicting the probability of defensive action

	B	S.E.	p value
Intercept	-.25	(.027)	**.03**
Income	-.062	(.027)	.03
Maximum Severity of Angina	.143	(.043)	.002
Doctor Visits for Angina	.013	(.017)	.47
Household Size	.064	(.051)	.22
Age	.015	(.008)	.08
Pack Years (thousand)	-.013	(.005)	.01
Near Smoker (Q S17)	-.166	(.122)	.18
Belief (Q 37)	-.116	(.078)	.15

$R^2 = .51$
N - 4 1

Note: Income is a categorical variable (see Question 21g). Maximum severity is the highest severity recorded in response to inquiry about seasonal differences in severity (Question 7).

The regression model, which explained 51 percent of the variability of the decision to undertake defensive action, suggests that this decision is related to factors that reflect current health status (greater angina severity, angina-related doctor visits), health concern and awareness (belief that angina attacks will harm the heart, rarely near smokers), past health habits (fewer pack years of smoking), demographics (age and household size), and lower household income. All of the coefficients were plausibly signed except income.

The regression results indicated that for the sample of 41 subjects for which the data were complete, the probability of a defensive action was positively associated with greater severity of angina attacks during the previous year, age of the subject, greater number of angina-related doctor visits, and larger household size. Of the positive associations, only the variable representing maximum severity was statistically significant (p = .002), However, age, one of the positive terms related to severity of disease and health concern, approached statistical significance (p - .08). The regression indicates that for a 10-year increase in age, the probability of a defensive action increases 15 percent.

A higher probability of defensive action was inversely associated with pack years of cigarette smoking, frequency with which subjects were around smokers, household income, and greater belief that the heart is harmed by angina episodes. Of these variables with negative associations, pack years (p = .01) and income (p - .03) were statistically significant. The inverse association of pack years and defensive action suggests that individuals who exhibit avertive behavior have smoked less over their lifetime and demonstrate a greater aversion to risk.

The inverse association of income and defensive action was an unexpected result since it indicated that those with higher incomes were less likely to have defensive actions. This association may be partly explained by the slight correlation (r - .29; p = .12) between income and bypass surgery (thus mitigating the need for further defensive actions); by the current health status of those who had a higher income and who were therefore more likely to be healthier and employed; or by the phrasing of the defensive expenditure question. Subjects with higher incomes are more likely to hire help with yardwork anyway and may therefore be less likely to attribute this expenditure to concern about angina.

Next, the factors that determined the amount of defensive expenditures were analyzed for the group of subjects reporting such expenditures (n - 21). Theoretically, the demand for defensive expenditures is expected to be related to income, the price of the potential purchase, the number of angina episodes that can "be reduced by the purchase, the severity of the current angina condition, risk perception, and demographic factors such as age and household size. As a pilot analysis with a small sample, an ordinary least squares stepwise regression procedure was used to determine how these variables would affect expenditures (Table 4.3-2). Because of the small sample" size, the number of independent variables was limited to four. Both household income and personal income were tested, while price was assumed constant through the one-year period. Variables were included to represent the number of episodes that were perceived to be reduced, heart attack history, the number of angina-related doctor visits in the last year, the perception of whether an angina episode added damage to the heart, the perception of the additional heart attack risk if an individual did not undertake the defensive action, age, and the number of people in the

Table 4.3-2. Regression analysis predicting the amount of defensive expenditures

	B	S.E.	p value
Constant	-22947		
Household Size	3035	(812)	.003
Age	271	(125)	.05
Angave	35.8	(36.3)	.34
Episaved	0.66	(3.24)	.84
R^2 = .40			
N - 2 1			

Note: Angave is the average frequency of angina based on Question 6. Episaved is the total number of angina episodes saved by defensive expenditures.

household. Unfortunately, since the sample size was so small, these results only indicate the explanatory variables that were most associated with higher defensive cost.

The results of the stepwise regression indicate that age and household size were highly associated with the level of defensive expenditures. Both were significant statistically, and together explained 40 percent of the variation in expenditures. The significance of household size may indicate changes in lifestyles, or that the members of the household, usually family members, may exert a protective influence on the heart patient. Age may be related to perceived risk or severity. Neither the "average" level of angina frequency (average of Question 6 across seasons) nor the number. of angina episodes that would be reduced were statistically associated with expenditures. Thus, the number of angina episodes currently experienced demonstrates an insensitivity to the costs associated with defensive expenditures. This result was reinforced during other regression analyses. When attempting to explain defensive expenditures per episode reduced, or the "price of an episode," an F-test was never significant.

Averting Behavior and CO Exposure

Since 18 of the 50 subjects had participated in earlier exposure monitoring research,we next examined the relationship between averting behavior and CO exposure. The level of subjects' exposure to CO was examined using the arithmetic average of personal exposure monitor readings over a 2-5 day monitoring period (see Section 4.4). The small sample size limits the inferences that can be made about these results.

We expected that the actual exposure would depend on current health status, attitude about the harmfulness of pollution, expressed desire to reduce pollution exposure, attitudes towards risk, voluntary contact with CO sources (e.g., amount of driving, proximity to gasoline-powered engines"on the job or at home), smoking status, socioeconomic factors, and degree to which other defensive action was undertaken. Several variables were"also included that would represent indoor exposures to CO since current research indicates that it is an important determinant of total CO exposure. Thus, variables indicating the use of a kitchen exhaust fan or opening of windows for ventilation and home insulation practices, were included among the candidate variables for selection. Again, an ordinary least squares stepwise regression procedure was used to observe the priority of entry into the model of the explanatory variables. The first three variables selected into the model (Table 4.3-3) were 1) whether the individual felt angina pain when walking at an ordinary pace on level ground; 2) whether the individual indicated that air pollution aggravated their angina; and 3) whether the individual was currently smoking.

Since personal tobacco use is a significant source of CO, the inclusion of smoking status was a reassuring result. Of particular interest, however, was the selection into the model of two variables which indicate possible averting behavior. If the angina subject gets an attack without too much strain, such as level walking, it suggests that he probably would do less walking and generally be outside less. Thus, exposure may be lessened if subjects do not walk on city streets or perform exertional activities such as using a gasoline-powered lawn mower. Conversely, increased reliance upon the automobile for transportation could increase CO exposure. The implications for exposure are therefore uncertain. The third variable, indicating that the

Table 4.3-3. Regression analysis predicting average carbon monoxide exposure

	B	S.E.	p value
Intercept	6.72		
WLKLEV3	-2.86	**0.79**	**.003**
SMOKE46	3.75	**1.60**	**.03**
POLL18	**-1.07**	**.66**	**.13**
R^2 - .69			
N - 18			

WLKLEV3 = **pain from angina when walking on level ground (Yes = 1; No - 0)**

SMOKE46 = **current smoker (Yes = 1; No - 0)**

POLL18 = 1 if yes to Question 18; otherwise - 0 - does air pollution bother your angina

subject feels his condition is aggravated by air pollution also may indicate less time outside and less active behavior. However, due to the small sample size and modest significance level, these results can only be viewed as suggestive.

These results, taken together, appear to indicate that behavior aimed at reducing the risks relating to exposure to CO was consistent with other choices made about health care and status by the subjects. For example, those with more severe angina were more likely to engage in defensive actions. They were more likely to hire household help and purchase equipment to reduce further risks of angina, and were likely to have reduced exposure to CO. Those who appeared to have greater concern for health or who were more risk averse, such as those who believed angina would increase heart attack risk and those who had smoked less in the past, were also more likely to undertake defensive behavior. Also of interest was the role household size appeared to play on health. Subjects from a larger household were more likely to hire help and purchase defensive equipment, and, among all those who had defensive expenditures, spent more. Although the analysis is limited by small sample size, it does suggest that defensive action may be an important aspect of health care and an important determinant of pollution exposure.

4.4 Community CO Exposures of IHD Subjects

Activity Patterns

In the sample of IHD subjects followed in the UC Irvine study, time spent in indoor residential microenvironment dominated the time-weighted classification of daily activities (Figure 4.4-1, Tables 4.4-1 and 4.4-2).

Figure 4.4-1. Proportion of time spent in major microenvironmental classes for nonsmoking IHD subjects while wearing the **CO** personal exposure monitors

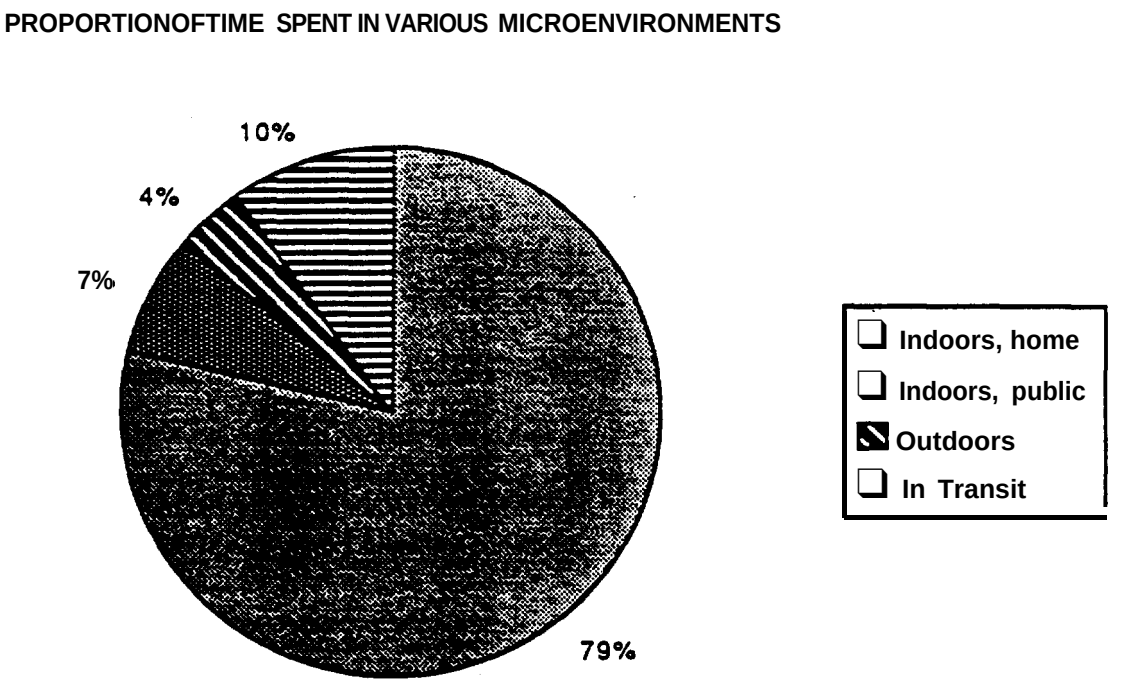


TABLE 4.4-1. Ranking of time-weighted exposures by activity class. Occupancy time refers to the time engaged in specific activity in a 24-hour period

RANK	ACTIVITY	CODE	TIME-WEIGHTED CO EXPOSURE (ppm-min)	GEOMETRIC MEAN OCCUPANCYTIME (rein)	GEOMETRIC MEAN CO CONCENTRATION (ppm)
1	Night sleep	45	825.6	471.0	1.8
2	Television viewing	91	245.4	91.5	2.7
3	Travel related to goods and services	39	244.1	39.7	6.1
4	Meals, snacks at home	43	130.4	47.5	2.7
5	Personal hygiene	40	91.7	38.4	2.4
6	Monitor attachment	38	81.5	27.8	2.9
7	Relaxing, thinking, doing nothing	98	80.7	29.5	2.7
8	Taking a walk	82	29.0	10.5	2.8
9	Resting	47	26.5	8.6	3.1
10	Reading books	93	21.7	7.3	3.0
11	Travel related to social activities	79	21.1	3.4	6.2
12	Preparing food	10	20.1	7.3	2.8
13	Travel to and from work	09	17.4	2.9	6.0
14	Meals at restaurant	44	16.0	3.9	4.1
15	Marketing	30	15.3	3.3	4.7
16	Readirrgnewspapars	95	14.3	4.7	3.0
17	Otherhousehofdduties	19	14.2	4.4	3.2
18	Civic participation	62	14.0	1.2	12.2
19	Visiting with friends	75	13.2	4.3	3.1
20	Regular work	00	13.1	4.5	2.9
21	Gardening, animal care	17	13.0	3.6	3.7
22	Waiting for goods or services	36	13.0	2.0	6.4
23	Travel related to personal care	49	11.2	2.6	4.4
24	Active sports	80	11.0	3.6	3.1
25	Travel related to organizational activity	69	10.8	1.8	5.8
26	Parties, receptions, picnics	76	10.2	1.5	6.8
27	Shopping for durable household goods	31	9.8	2.7	3.6
28	Social activity at cafe or bar	77	9.3	1.1	8.8
29	Personal care	32	8.5	1.1	7.5
30	Medical care	33	8.4	2.5	3.3
31	Other household upkeep and repairs	16	8.0	2.4	3.3
32	Travel related to study or school	59	7.9	1.1	7.4
33	Work (for pay) at home	01	7.8	1.8	4.4
34	Repair services	35	7.5	1.2	6.2
35	Travel related to active leisure	89	7.5	1.7	4.4

TABLE 4.4-1 Con't.

RANK	ACTIVITY	CODE	TIME-WEIGHTED CO EXPOSURE (ppm-min)	GEOMETRIC MEAN OCCUPANCY TINE (rein)	GEOMETRIC MEAN CO CONCENTRATION (ppm)
36	Clothes care	15	7.3	1.1	6.5
37	Conversations	96	7.2	2.4	3.0
38	Travel with child	29	.6.9	1.2	5.7
39	Outdoor chores	13	6.8	2.9	2.3
40	Meal cleanup, doing *dishes*	11	6.4	1.3	4.9
41	obtaining other services	37	6.3	1.1	5.8
42	Religious activities	64	5.9	1.2	4.8
43	Travel related to passive leisure	99	5.8	1.2	5.0
44	Daytime sleep	46	5.8	1.2	4.8
45	House cleaning	12	5.4	2.1	2.5
46	Work breaks	08	5.1	1.3	4.0
47	Child care	21	4.9	1.1	4.3
48	Other classes or courses	51	4.9	1.2	4.0
49	Waiting, delays at work	04	4.6	1.1	4.3
50	Volunteer activities	63	4.3	1.6	2.7
51	Hobbies	83	4.4	1.2	3.8
52	Reading or writing tatters	97	4.1	1.3	3.2
53	Playing records or tapes	92	4.1	1.1	3.7
54	Travel for job	03	4.0	1.3	3.2
55	Government or financial services	34	3.9	1.7	2.2
56	Palor games	87	3.8	1.6	2.4
57	Meals at work	06	3.8	1.3	2.9
58	Household activities related to heat or water	18	3.0	1.2	2.5
59	Radio listening	90	2.9	1.3	2.3
60	Religious practice	65	2.9	1.2	2.3
61	Personal medical care	41	2.4	1.2	2.0
62	Making music	86	2.1	1.2	1.8
63	Reading magazines	94	1.8	1.3	1.4
64	Private activity	48	1.6	1.2	1.3
65	Outdoor playing with children	25	1.5	1.2	1.4
66	Other active leisure	88	1.4	1.1	1.3
67	Laundry, ironing of clothing	14	1.4	1.2	1.2
68	Fishing, hiking	81	1.3	1.1	1.2
69	Entertainment events	71	1.3	1.1	1.2
70	Sports events	70	1.1	1.1	1.0

TABLE 4.4-2 Ranking of time- weighed exposures by microenvironment class. Occupancy time refers to time spent in location class.

RANK	MICROENVIRONMENT	CODE	TIME-WEIGHTED CO EXPOSURE (ppm-min)	GEOMETRIC MEAN OCCUPANCY TIME (rein)	GEOMETRIC MEAN CO CONCENTRATION (ppm)
1	Bedroom	115	786.0	436.8	1.8
2	Personal Auto	310	357.2	63.8	5.6
3	Living Room	114	242.0	87.6	2.8
4	Kitchen	112	59.7	20.6	2.9
5	Indoors, home, unspecified	110	60.9	20.1	3.0
6	Bathroom	116	56.7	26.1	2.2
7	Hospital (includes monitor attachment)	138	56.5	10.2	3.1
8	Outdoors, around the house[1]	210	45.7	14.9	3.1
9	Store, post office, barbershop	132	27.9	6.4	4.4
10	Dining room area	113	25.2	0.7	2.9
11	Restaurant	131	17,8	4.2	4.3
12	Family room, den	111	15.8	5.4	2.9
13	Truck	311	12.9	1.7	7.7
14	Occupational Health Center Van	317	12.8	1.4	9.3
15	Meeting hall, lodge, clubhouse	147	10.8	2.9	3.7
16	Indoor gymnasium or swimming facility	142	10.2	1.2	8.3
17	Within 10 yards of active roadway	212	9.7	3.2	3.0
18	Work area (assemblyline, shop, warehouse)	122	9.1	2.7	3.3
19	Shopping mall	133	8.9	2.0	4.4
20	Outdoors, service station or motor vehicle repair facility	214	8.0	1.3	6.1
21	Parking lot or carport (open car building)	213	7.7	1.5	5.1
22	Indoors, service station or other motor vehicle repair facility	144	7.6	1.1	7.0
23	Indoors at home of friend	146	7.6	2.4	3.2
24	Indoors, unspecified	100	7.2	1.2	6.2
25	Garage or enclosed carport	118	6.5	2.4	2.8
26	Motor home	318	6.1	1.2	5.2

[1]Yard, patio, outside house, within building areas but not in own unit.

TABLE 4.4-2 Con't.

RANK	MICROENVIRONMENT	CODE	TIME-WEIGHTED CO EXPOSURE (ppm-min)	GEOMETRIC MEAN OCCUPANCY TIME (rein)	GEOMETRIC MEAN CO Concentration (ppm)
27	Indoors, home, other room	119	6.0	1.0	5.7
28	Bus	312	5.8	1.1	5.1
29	Motorcycle	313	5.4	1.1	4.9
30	Church	135	5.4	1.6	3.5
31	Neighborhood residential streets	211	5.3	3.6	2.3
32	school	136	5.1	1.3	4.1
33	Park, golf course, outdoor recreation area, beach	215	5.0	1.6	3.2
34	Lunchroom, breakroom	123	5.0	1.2	4.3
35	Office, public place	134	4.6	1.8	2.6
36	Bowling alley	141	4.6	1.1	4.1
37	Outdoor store, lumber yard, nursery	220	4.2	1.1	4.0
38	Walking	314	4.2	1.1	3.7
39	Office, work area	121	4.2	1.6	2.6
40	Indoors, public place, unspecified	130	3.7	1.1	3.4
41	Outdoors, walking	230	3.4	1.3	2.6
42	Home laundry room, workshop, utility room	117	3.3	1.4	2.3
43	Jogging or brisk walk for exercise	316	2.9	1.1	2.6
44	Bicycle	315	2.9	1.3	2.2
45	Outdoors, truck yard	231	2.8	1.2	2.3
46	Hotel/motel room	148	2.7	1.3	2.0
47	Diesel truck	319	2.6	1.2	2.2
48	Bicycle path	219	1.9	1.2	1.5
49	Outdoors, unspecified	200	1.4	1.0	1.3
50	Dance hall	140	1.3	1.1	1.2
51	Indoors, work, unspecified	120	1.2	1.1	1.1
52	Library	149	1.1	1.0	1.0

The subjects spent 79 percent of their monitoring day in their residence. Night sleep and bedroom were the single largest duration activity and microenvironment location occupied each day. Television viewing and other passive leisure activities largely took place in the living room or family room. Resting and relaxing activities were generally associated with the. indoor residential environment. Time in personal auto accounted for most of the 10 percent of daily time spent in transit microenvironment. Generally, these values are comparable to those published for the general population (Chapin, 1974; Robinson, 1977; Ziskind et al. 1982). Daily time devoted to walking for exercise (10.5 minutes) and active sports (3.5 minutes) is substantially less than the 90 minutes national average for all age classes combined (Chapin, 1974).

Time activity patterns have important implications for myocardial oxygen demand. Several classes of activity are associated with very high myocardial oxygen demands. These include regular work at a job site or at home; outdoor chores at home; lifting work at home such as carrying firewood or moving furniture; exercise and outdoor recreation; sexual activity; and travel such as bicycling or walking, and driving in stressful situations. However, in the IHD subpopulation sampled, the occurrence of these strenuous activities was relatively infrequent, not only in terms of the number of occurrences but also in terms of the number of subjects choosing to engage in such activities. As indicated by the low geometric means, sustained intervals of heavy activity were uncommon across the aggregate. Yet certain subjects who were inclined to do heavy work did undertake such activity on a regular routine and, at times, maintained high levels of exertion for periods as long as two hours. Interviews revealed that though these subjects were prone to exertional angina, they were able to undertake heavy activity if they paced themselves.

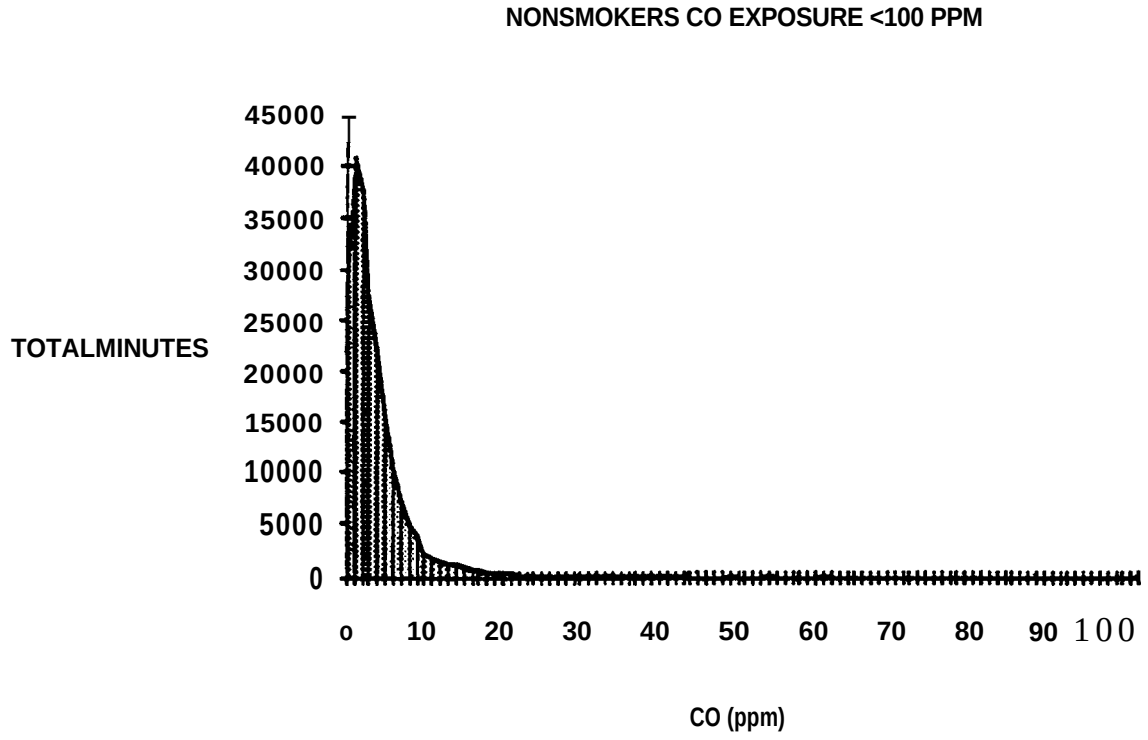
These activities included heavy carpentry, auto repair, and cutting firewood. During the intervals, very high levels of exertion were achieved.

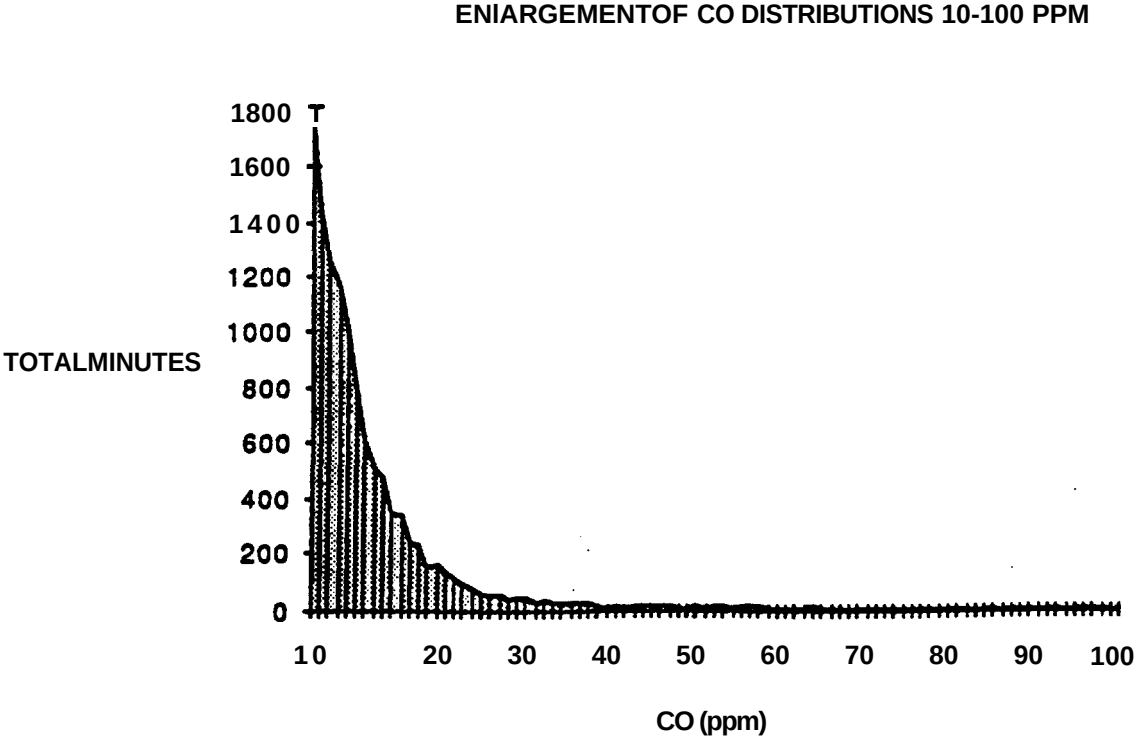
Walking for exercise represents the upper level of daily exertion for the majority of the IHD subjects studied in this effort (98 separate occurrences by 25 unique subjects). For most subjects it is a walk at a pace that is just slightly below their personal threshold of angina. It was not unusual for angina symptoms to be reported during walking exercise. During separate graded exercise testing on a treadmill using a modified Naughton protocol, the majority of the subjects identified a workload of 3-4 METs (i.e., 3-4 times the resting metabolic rate) as subjectively equivalent to their personal level of perceived exertion during walking. Thus, a low functional capacity was characteristic of this IHD group selected for study.

Community CO Exposure

The highest CO exposures occurred during commuting and when near internal combustion engines. Average personal exposures were elevated during city street and freeway driving, and while in parking lots and automobile service stations (Tables 4.4-1 and 4.4-2). In contrast, residential exposures were generally low, allowing CO absorbed by the body while at other locations to wash out of the blood during the time spent at home. High short-term exposures were found in proximity to small gas-powered garden equipment. Transient peaks as high as 134 ppm were observed with use of a chain saw and 226 ppm with use of a lawn edger. Occupational exposures were highly variable with elevated exposures associated with warehouses, assembly lines, and garages. Generally, CO exposures remained below the federal standards of 35 ppm for l-hour and 9 ppm over 8-hours (Figure 4.4-2).

Figure 4.4-2. Distribution of minute-by-minute personal CO exposure measurements for nonsmoking subjects (N=36; 142 person days)

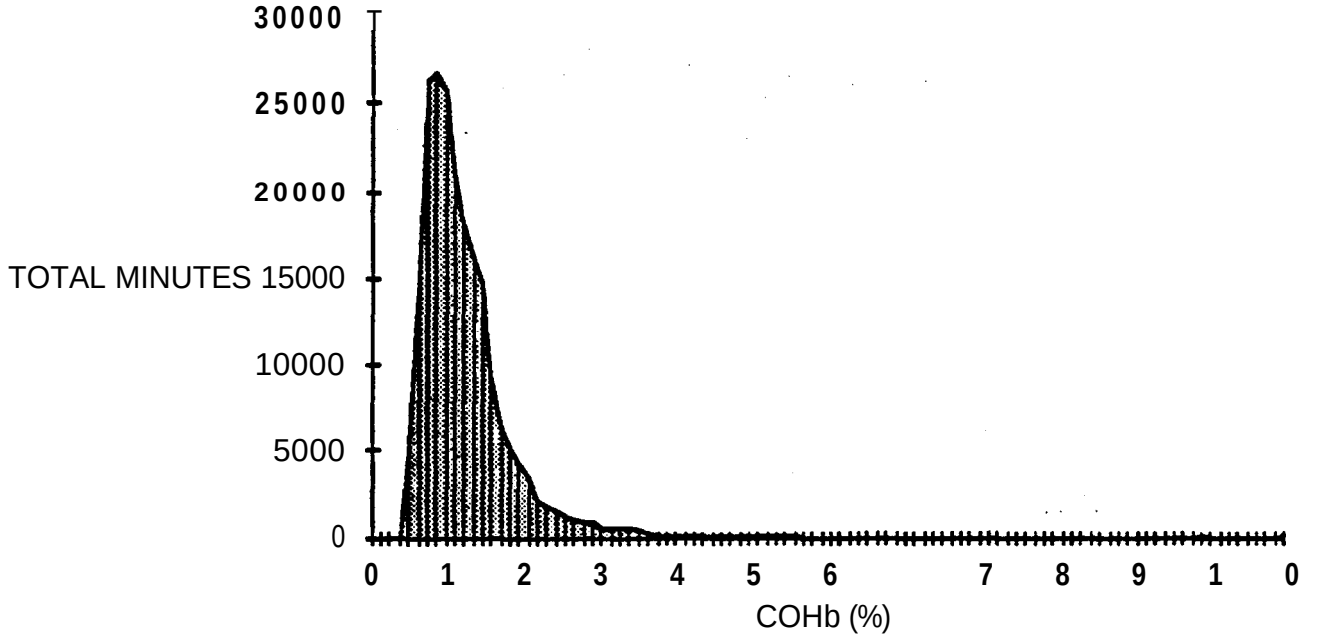


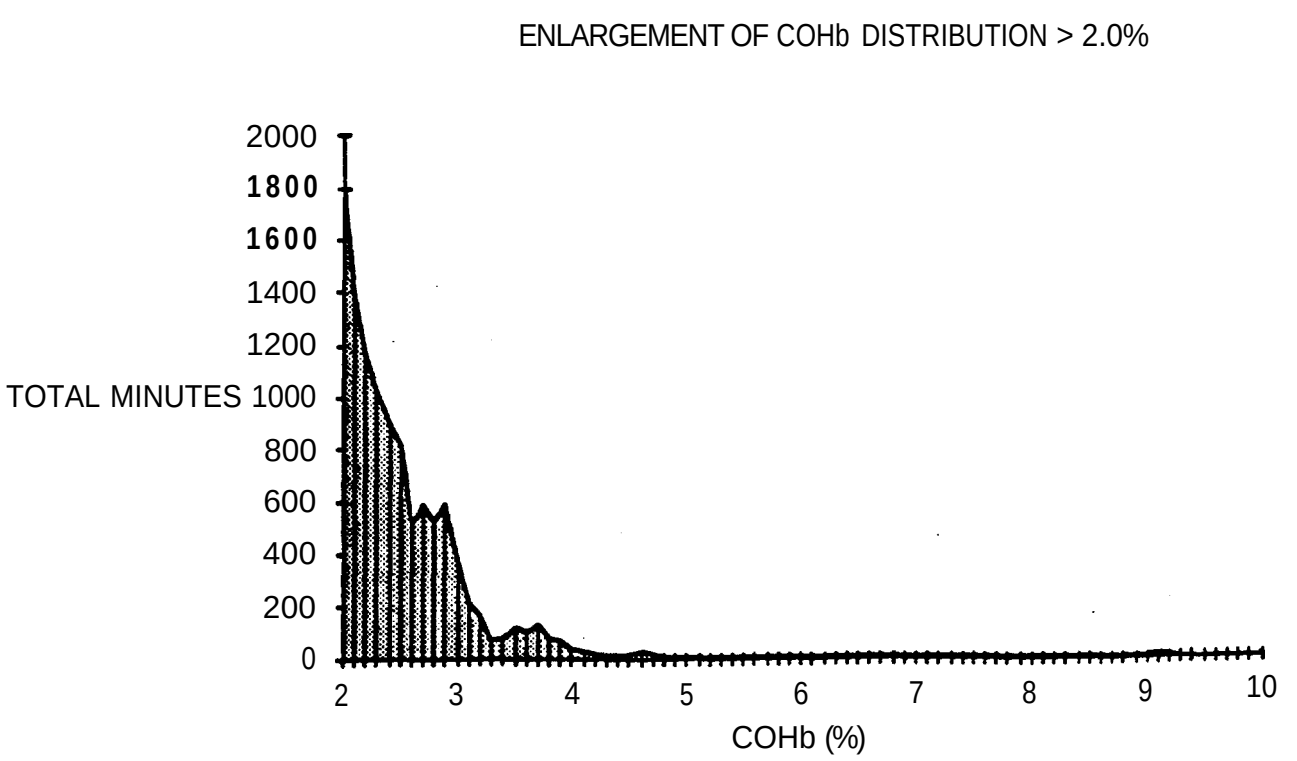


Activity data and microenvironmental CO exposures were combined to estimate the accumulation of CO in the blood. Coburn et al. (1965) have determined that several physiologic and environmental factors regulate CO flux : inhaled CO concentration, endogenous CO production, barometric pressure, diffusing capacity for CO, alveolar ventilation, blood volume, mean capillary oxygen tension, and oxyhemoglobin concentration. Duration of occupancy of microenvironment will determine uptake and washout, and the degree to which blood carboxyhemoglobin attains steady state with the setting's CO concentration. Increased levels of physical activity within a microenvironment will speed the rate at which uptake or elimination to steady state COHb is achieved. Strenuous activity such as exercise or yardwork is associated with increased minute alevolar ventilation and increased diffusing capacity for CO. An increase in either or both of these physiologic factors increases CO flux. Strenuous levels of activity were relatively infrequent across the IHD sample group. In general, the subjects' highest level of exertion would still be considered moderately light for individuals free of coronary artery disease. For these reasons, the requirements of uptake and elimination modeling become simplified and a linear model can be applied (Ott and Mage, 1978). This model assumes light physical activity and does not incorporate the input of individual physiologic parameters as the Coburn equation does. Preliminary analyses indicate that 56 percent of the IHD subjects experienced COHb levels in excess of 2.5 percent during the 142 person days of monitoring, corresponding to 1.8 percent of the total monitoring time (Figure 4.4-3).

Federal standards for ambient air are designed to prevent accumulation of CO in the body to levels where health effects have been demonstrated. The standards are set at 9 ppm for 8 hours and 35 ppm for one hour. Individuals

Figure 4.4-3. Distribution of minute-by-minute COHb estimates as predicted for nonsmoking IHD subjects by PEM measurements using the linear model of Ott and Mage (1978) (N=36; 142 person day





exposed to CO at these concentrations and durations would develop carboxyhemoglobin levels of approximately 1.5 percent, a level below the 2-4 percent carboxyhemoglobin range at which exercise performance is impaired in people with ischemic heart disease (Anderson et al., 1983). Thus, the standards are set at levels which are intended to provide a margin of safety.

CO concentrations in microenvironment iocations are poorly correlated with those measured at nearby outdoor sites (Ott et al., in press; HartWell et al.,1984) . Personal exposures experienced in settings such as commuting on freeways **or** walking on a roadside path may be several-fold higher than CO concentrations measured at the nearest ambient monitoring site. Further, it is reasonable to speculate that depending upon the conditions of the exposure (e.g., concentration, duration, breathing rate), the resulting carboxyhemoglobin concentrations may be elevated to levels higher than those estimated from outdoor fixed-site monitors. Further research is needed to address the relationship between ambient measurements and carboxyhemoglobin levels in the population. Alternative placements for monitors may give a more reliable measure of the actual personal exposures and the protection afforded to IHD subjects by the present federal standards.

4.5 Conclusions and Recommendations

4.5.1 Introduction

There are many components of an analytical evaluation of alternative carbon monoxide standards. Section 2 presented one theoretical framework, an economic model of individual behavior, which can, when aggregated over individuals, be used to evaluate different carbon monoxide standards. In this

framework, a person's utility is a function of health and goods or services consumed. The level of a person's health is modeled as a function of defensive expenditures D, pollution exposure P, and biological, social, and economic characteristics of the person (21). It is assumed that a person maximizes utility, which is constrained by available income through an income constraint. Income may be deflated by previous expenses due to medical expenditures or by foregone wages due to loss of work.

In this project, we have gathered four kinds of information on the adverse effects of ischemic heart disease, including time spent sick (resulting in lost days of work or partial or full loss of employment) and medical expenditures made in response to illness (Section 4.1), rankings of the relative bothersomeness of the effects of angina/heart disease (Section 4.2.1), willingness to pay to avoid additional angina (Section 4.2.5), and defensive expenditures and activities (Section 4.3). We also have done 'a secondary analysis of data collected on personal CO exposure in the urban setting (Section 4.4).

We have thus developed a feasible framework for eliciting many of the components required for the evaluation of the impacts of carbon monoxide exposure on ischemic heart disease patients who experience angina pain. Additional components that still must be determined through other research efforts are

1. defining the relationship between carbon monoxide standards and resulting personal exposures to carbon monoxide in microenvironment;
2. quantifying the number of additional angina episodes per month that would occur due to changes in personal exposures to carbon monoxide, (the type of information that is needed will be of the form, "if the personal CO exposure is changed by an increment so that the average

level of carboxyhemoglobin (COHb) in the blood goes from 2 percent to 1 percent, and peak levels go from 3.5 percent to 2.5 percent, there would be x fewer angina episodes per month for people with moderately severe angina.");

3. characterizing the functional relationship between defensive expenditures (D), pollution exposure (P), and personal characteristics (21) in the health production function.

4.5.2 Summary of Results

Using multiple measures, the results converge on a picture of ischemic heart disease as a burdensome health state, with substantial medical costs, losses of opportunities to earn wages, psychological stress, and expenditures to avoid further adverse health effects.

Cost of Illness

Annual out-of-pocket medical expenditures due to ischemic heart disease for this sample averaged $256 per person. This included out-of-pocket medical expenditures for treatment and medication and travel to the physician's office. It is important to note that this sample was dominated by VA patients who may have lower out-of-pocket expenses than the average IHD patient. Total annual medical expenditures due to heart disease incurred by society (including the VA, private insurers, but not the individual) averaged $4,523 per person. For the 15 employed subjects, the average annual income lost due to time lost from the regular work schedule because of angina was about $347. For the 19 subjects working less than they would like due to angina

(including those unable to work at all) the average annual income lost was about $24,940. Thus, the total average annual loss due to medical expenditures and lost income (by the individual or on behalf of the individual) totalled $14,359 per person across all 50 subjects. Because CO is believed to aggravate angina symptoms in patients who already have IHD, analysis was undertaken to estimate the marginal costs of small changes in angina frequency. The results suggest that although the total costs associated with IHD are substantial, the marginal cost of small changes in angina is minimal.

Lifestyle/Emotional/Physical Effects

In general, the subjects reported that the most bothersome effects of a potential increase in angina would be less ability to do desired activities (recreation, chores, or work), and pain or discomfort. The next two most bothersome effects were the patients' concern about worry or inconvenience to family and friends, and concern about the possibility of having a heart attack or bypass surgery. The remaining effects, in order of decreasing bothersomeness were less ability to work at a job (for reasons other than income), more non-medical expenses (such as paying for services), more medical treatment expenses, and less ability to earn income.

Willingness to Pay

The mean willingness to pay to avoid angina was $40 per episode among the 42 subjects who responded with a dollar amount. When respondents who gave the answer "I'd pay anything I have to avoid added angina" were coded to be equal

to the highest amount they had agreed to when asked a close-ended question of the form "Would you pay $y per month to avoid four (or eight) additional angina episodes per month?", the lower bound on the willingness to pay for all 49 responding subjects was $42 per month. When those who would pay "anything" had their answers recoded to a feasibly maximum amount equal to their total monthly income, the average willingness to pay was $103 per episode.

Expenses Due to Defensive Expenditures

Subjects were asked to itemize expenditures they made for goods or services to avoid additional angina. Twenty-one of the 50 subjects hired services (e.g., yard work, plumbing, or car maintenance), yielding an average annual expense of $2,151, for these subjects. Sixteen of the 21 subjects estimated the number of added angina episodes they avoided by hiring services. The mean expenditure per episode for these 16 subjects was $38, and ranged from $3.50 to $140. This mean may be compared to the average stated willingness to pay of $28 per angina episode given by the same 16 subjects in response to Question 33.

Comparison of Alternative Dollar Measures of Changes in Well Being Due to Changes in Angina

Table 4.5-1 summarizes the dollar welfare estimates obtained from this Study. The cost of illness estimates listed in the first section of the table are annual costs associated with all aspects of the heart disease. The figures given are averages for our sample, which should not be interpreted as representative of all IHD patients because the sample was not randomly

Table 4.5-1. Summary of dollar welfare estimates for ischemic heart disease patients

A. Average annual expenses related to IHD*

Cost of illness expenses:

Medical expenses incurred by patient: (OPSUM2 = Sum of out-of-pocket medical expenses, iess insurance premia. Cost of travel to obtain medical care included.)	$256
Medical expenses paid by insurance or VA: (SOCSUM2 - OPSUM2)	$4,523
income Lost TWKLOSS = Empioyer paid sick days' cost and Lost wages due to angina (SWKLOSS)	$9,581
Total cost of illness (COISOC)	$14,360
Defensive expenditures .*	903
Total IHD-related expenses (N = 50)	$15,263

B. Alternative estimates of average willingness to pay per angina episode avoided for small changes in angina frequency

	Mean WTP per episode
1. Finite responses to open-ended contingent valuation question	$40 (N= 42)
2. Defensive expenditure for specified, angina reduction	$38 (N= 16)

* These estimates are averages for our sample, which is not necessarily representative of all IHD patients. These costs varied considerably from one individual to another.

** This represents total defensive expenditures listed by each subject. For 29 subjects, this was $0. The average for the 21 subjects with some defensive expenditures was $2,151.

selected. In particular, medical insurance coverage may be greater than average because many of the subjects were completely covered by the Veterans Administration.

The second section of Table 4.5-1 shows the two alternative willingness to pay estimates obtained for small changes in angina frequency. We do not give any cost of illness estimate here because the analysis suggested that such costs do not vary significantly for small changes in angina frequency. The cost of illness (COI) approach has historically been the one most frequently used. Analysis of the COI data obtained for this sample did not show any significant relationship between costs and angina frequency. This suggests that the marginal welfare impact (as measured by COI) of marginal change in angina frequency is minimal. However, other information obtained in this study suggests that marginal changes in angina frequency do have a significant welfare impact. The willingness to pay and defensive expenditures analysis, when adjusted to per angina episode avoided, are generally comparable and in the range of $25 to $100 per episode. Even though there are significant concerns in accurately estimating economic value measures for changes in angina using willingness to pay and defensive expenditure approaches, their consistency with one another, and with the rankings of impact categories, suggest they may be more likely to accurately represent the value of marginal changes in angina than the results of a COI analysis.

Activity Patterns and CO Exposure

Data on activity patterns and CO exposure in urban locations was collected in an earlier UC Irvine research effort. An analysis of this data suggested that IHD patients frequently encounter CO in the course of their

daily activities and may develop COHb levels greater than 2.5 percent, a point where aggravation of angina has been observed in clinical studies.

4.5.3 Recommendations for Further Research

Several recommendations for further research have resulted from this pilot study. A subsequent larger study, with more funding, should include the suggested revisions and expansions. The recommendations are divided into the following three categories: carbon monoxide exposure, health effects resulting from CO exposure, and valuation of health effects in ischemic heart disease patients

Carbon Monoxide Exposure

* Conduct further studies to link microenvironmental CO exposure to exposure at outdoor fixed-site monitors. Investigate the possibility of selecting alternative placements of monitors for more reliable measure of actual personal exposures.

Health Effects Resulting from CO Exposure

* Conduct further studies to link actual personal CO exposure and angina by developing a dose-response curve which may be applied in the natural exposure environment of the community.

Valuation of Health Effects in Ischemic Heart Disease Patients

* Conduct further contingent valuation studies with modifications suggested by this study and with a larger and more representative sample of IHD patients. This work would implement further tests of

the valuation methodology, such as investigating yea saying on referendum willingness to pay questions.

* Conduct longitudinal studies following "healthy" people at risk of developing IHD (e.g., overweight males aged 35-50 with high blood pressure). Attitudes, behaviors, and willingness to pay to avoid symptoms would be monitored over a number of years. Preferences are expected to change with the onset of symptoms and over 'the developmental course of coronary disease.
* Extend the framework developed for valuing angina in this project to consider explicitly the whole complex of health outcomes including heart attacks and cardiac death.
* The present study assumed certain expenditures or behaviors were motivated by a desire to avoid additional angina. Further time-activity studies should explore how averting behaviors are chosen by angina patients, asking subjects to supply concurrent reasoning behind the choice of activities. People may consciously make tradeoffs between the costs of accepting more angina and the benefits of engaging in more activity.
* It is important to understand how subjects are framing the valuation questions. For example, when a subject states his willingness to pay to avoid one additional angina episode is $50, he may mean that $50 is the sum total of actual costs incurred by one extra angina episode (e.g., due to doctor's office visits and medication), plus foregone wages due to work loss from the one episode, plus defensive expenditures (e.g., hiring a yard worker for that day), plus extra pay for pain and suffering. Alternatively, he may mean that $50 is only the amount of extra pay for pain and suffering, or that it is his

maximum for any "similar" illness episode. Further, he also may mean that this is a measure of how much it would be worth to be "cured" of heart disease totally. The actual interpretation used by the subject may be discernible by follow-up questions in the survey. Then subjects could be divided into groups based on the concerns focused on, and separate analyses could be conducted for the subsample. To counteract the problem of shifting question framings, contingent valuation willingness to pay questions could be asked in several formats to focus the framing on the components which might be included in a person's response. For example, asking: "If you get one added angina episode out of four times you mow your own lawn, will you hire someone to mow your lawn all four times if it costs $100?," will frame the amount as a defensive expenditure. Different framings would isolate the other components. In addition, the realism of the context for payment to avoid added episodes and believable degrees of incremental changes in number of episodes for each type of subject should be investigated.

* Consider collecting representative prototypical patients and interviewing them in depth to determine their valuation of added adverse health effects. A decision analysis procedure in which each person's multiattribute utility function is assessed, and the preferences of the group of people are then aggregated, probably would work well in this setting.

* Conduct studies to determine if the willingness to pay to avoid multiple health endpoints is additively cumulative. For example, a person with heart and lung disease may be adversely affected by carbon monoxide exposure in at least two ways: additional angina episodes

and obstructed breathing. A study could assess willingness to pay to avoid changes in all health endpoints at once and the results could be contrasted with those when subjects consider one health endpoint at a time. Then a formal model of whether the added effects have a diminishing effect on the cumulative willingness to pay could be constructed.

* Obtain provider-verified medical expenses to improve the accuracy of the medical cost analysis.
* A more extensive study also could obtain a larger data base on employment status and earning. Then an alternative average measure of workloss impacts could be obtained by using analytic statistical techniques to examine the effects of the existence and severity of IHD and angina on employment and earnings. However, a person's perceived work loss still is needed to evaluate and interpret the willingness to pay responses.
* Assess values for two levels of change in angina episodes both across subjects (as in the pilot test for 4 and 8 episodes per month) and for each subject.
* Assess perceived changes in cost of illness which would be associated with the hypothesized changes in angina incidence (i.e., 4 or 8 episodes) in the contingent valuation willingness to pay questions.
* The pilot testing suggests that analysis of averting expenditures appears promising. This work can be pursued with more extensive modeling and data collection on multiple averting activities and on the resultant impacts on multiple health endpoints.

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